INDEPENDENT TECHNICAL ASSESSMENT

# Environmental Monitoring and Assurance at the Cloughton 2 Wellsite

*A comparative assessment of UK legal requirements, European environmental standards and internationally recognised technical practice*

**Burniston Mill, North Yorkshire | Draft permit EPR/YP3623LC/A001**

| | |
|---|---|
| **Prepared by** | Daniel Nye, independent citizen researcher |
| **Version** | 1.1 - revised consultation technical report |
| **Date** | 6 August 2026 |
| **Evidence cut-off** | 6 August 2026 |
| **Status** | Revised technical assessment; includes incident-derived failure-mode review |

## Central question

*Does the present application and draft permit establish a monitoring and response system capable of detecting, attributing, reconstructing and responding to the material environmental behaviours that could plausibly arise during construction, drilling, stimulation, testing, restoration and aftercare?*

# Document status, scope and limitations

This report audits the public application package and draft Environment Agency decision against the legal and technical standards identified in the report. It distinguishes binding requirements from persuasive guidance and comparative European or international practice. Version 1.1 incorporates the updated 2026 Waste Management, Waste Gas Management and Surface Water Management Plans, and adds an incident-derived review of known assurance failure modes. It is not legal advice, a causal determination, or a finding that pollution or harm will occur.

The analysis is deliberately prospective. A “gap” means that a material element is absent, deferred, under-specified, spatially or temporally limited, or incapable of answering the stated monitoring objective on the documents presently available. A gap is not automatically a statutory breach. Some gaps can lawfully be controlled by pre-operational conditions; the separate question is whether the resulting assurance is scientifically testable and meaningfully reviewable before the principal permit decision.

Page references to application documents are PDF page numbers in the reviewed files. Legislative and guidance sources were checked against official UK, EU, ISO, HSE, NSTA and Environment Agency publications available on 6 August 2026.

## Legal-status key

| Class | Meaning |
|---|---|
| A — Binding | UK legislation, permit conditions and incorporated operating techniques. Non-compliance may be enforceable. |
| B — UK regulatory guidance | Not legislation by itself, but normally relevant to how the Environment Agency interprets adequate applications, monitoring, BAT and management systems. |
| C — EU-derived domestic framework | EU requirements implemented through surviving UK domestic law. The domestic instrument, not the Directive alone, is binding in England. |
| D — Current EU comparator | Current EU law or policy that does not directly bind a UK site after EU exit, but may evidence contemporary European environmental practice. |
| E — International technical benchmark | ISO, EN and other recognised standards. Persuasive evidence of competent methodology unless incorporated into a permit, contract or legal duty. |
| F — Applicant commitment | A technique or promise in the application. If incorporated into the permit it may become enforceable; if deferred, its final content is unresolved. |

# Executive summary

### Overall conclusion

The application is not devoid of monitoring or control. It contains a substantial containment design, a comparatively strong acoustic assessment, a detailed odour complaint framework, proposed weekly groundwater sampling during drilling and testing, and continuous flare process parameters. The central weakness is architectural: decisive baseline, fault, fracture, trigger and response information remains deferred, while the monitoring that is specified is mainly model-confirmatory, site-boundary focused and domain-specific. The present package does not yet demonstrate a single system capable of detecting and reconstructing transient, off-site, cross-domain or conceptually unexpected environmental signals.

The strongest findings are as follows:

- The Environment Agency expressly records that the submitted Site Condition Report does not contain the Article 22 baseline report and relies on PO 01 to obtain groundwater design, parameters, interpretation methods and trigger levels after permit grant. The permit prevents operation until approval, but the baseline architecture is not available for the principal public decision. (A1, pp. 25–26; A2, pp. 15–16)
- The proposed three-month groundwater baseline meets the Environment Agency’s stated basic minimum, but the same guidance says more samples are needed where seasonal variation must be identified. The site documents acknowledge seasonal waterlogging, perched groundwater in sand and gravel pockets, active nearby springs and a multilayered bedrock aquifer. A three-month window is therefore not shown to represent the annual range. (A4, pp. 25–29, 33–34; UK4–UK5)
- All three proposed boreholes monitor the upper bedrock aquifer. The HIA acknowledges potential perched aquifers in superficial deposits but provides no separate shallow installation. The proposed long screened interval

may also integrate groundwater from more than one horizon. The final design remains deferred. (A4, pp. 28, 33–34; A1, p. 24; ISO2–ISO3)

- The Surface Water Management Plan samples water retained inside the perimeter ditch for classification and off-site disposal. It does not establish upstream/downstream or control monitoring of Burniston Beck, nearby ditches, ponds, springs or sediment. No general rule requires all such receptors to be sampled, but the submitted system cannot itself demonstrate whether an off-site change occurred. (A6, pp. 13–18; A4, pp. 4–5, 33–34)
- The Air Quality Monitoring Plan uses two operator-consultant-selected locations, four-week passive samples, one-minute grabs and a 30-minute mobile methane perimeter walk. These methods can characterise averages and screen for leaks, but cannot reliably reconstruct a short release or provide rapid attribution. Results may arrive 20 working days after retrieval. (A7, pp. 15–18; UK6–UK7; EU5)
- The detailed Hydraulic Fracture Plan, including fault mapping, stresses, stages, pressures, volumes, fracture-control procedures and seismic monitoring, is deferred to PO 08 at least two months before stimulation. This is a meaningful operational control, but the current package does not permit independent review of the final geomechanical model or monitoring design. (A1, pp. 23–24, 74–76; A2, p. 17)
- The decision records that no dedicated Accident Management Plan was submitted. The Environment Agency considers dispersed controls sufficient, although its current management-system guidance states that a plan is needed for incidents or events that could cause pollution or permit non-compliance. This is best characterised as a documentary and integration gap rather than a concluded statutory breach. (A1, p. 28; UK8)
- NORM waste controls are present: formation and flowback water are to be analysed by gamma spectrometry and managed under RSR controls where applicable. There is, however, no pre-disturbance radiological baseline for soil, water, sediment or ambient gamma against which a later off-site observation could be compared. That is a technical attribution gap, not a demonstrated legal omission. (A9, pp. 37, 49–50, 55; UK10)
- The package contains no repeatable pre-construction baseline for ground elevation, settlement, cracks, drainage geometry, new ponding, seepage or vegetation condition. Soil chemistry alone cannot reconstruct hydro-mechanical or drainage change. (A5, pp. 33–34; ISO4–ISO5)
- Complaint and monitoring systems remain compartmentalised. Odour tracking is relatively detailed, but no overarching protocol requires coincident water, air, pressure, seismic, noise, radiological and ecological observations to share one event identifier, preserve relevant data and trigger conceptual-model review. (A9, pp. 61–63; A12, pp. 123–126; A13, pp. 31–35)
- The updated Waste Gas Management Plan is expressly a BAT assessment for the production-testing phase. The drilling layout identifies shaker, settling, mix and cuttings tanks but does not identify a degasser, mud-gas separator, enclosed return system, vent or abatement route. The well-testing plan, by contrast, expressly identifies a gas scrubber and vent, gas knock-out and flare. This does not establish that drilling-return emissions will be uncontrolled; it establishes that the complete drilling-phase source and control chain is not yet demonstrated.
- The shrouded-flare assessment accepts reduced or slightly lower combustion efficiency relative to an enclosed flare while relying on expected performance above 98%. The permit provides continuous process monitoring but may dispense with direct periodic pollutant testing where the flare operates for less than 10% of the year. Nominal efficiency and operating parameters should therefore be supplemented by first-use and representative performance verification.
- PO 08 requires proposed measures to monitor local seismicity, but the consulted package contains no station geometry, baseline period, detection objective, location uncertainty, strong-motion coverage or post-injection monitoring duration. Preston New Road used eight local surface seismometers, a 12-geophone downhole array and at least four ground-motion monitors. Cloughton need not reproduce that exact arrangement, but equivalent site-specific detection and event-location capability has not yet been demonstrated.
- Formation water and flowback are routed generically to an Environment Agency-permitted treatment facility. The public package does not name the receiver, demonstrate waste-specific acceptance and treatability, account for contaminants transferred into sludge or sediment, or reconcile the final mass and environmental fate. A permitted route is not by itself proof of technical suitability for the actual waste.
- Wheel washing is specified as a construction-dust control. It is not described as a chemical, saline, hydrocarbon or NORM decontamination system. Because the pad-wide membrane is relied upon as tertiary containment after primary or secondary failure, vehicles, mobile plant, hoses, tools and personnel must be treated as possible carriers across the containment boundary.
- The revised pathway test follows each material through gas, liquid and solid phases; natural, well and engineered pathways; authorised and unintended transfers; mobile carriers; off-site treatment; and cross-phase transformation. The governing question is not only whether a control exists, but whether the final fate of every material can be measured and reconstructed.

## Priority action before activities commence

The permit should be strengthened so that all material pre-operational plans form a coherent, auditable assurance system. At minimum, the regulator should require:

- a completed Article 22 baseline report and a monitoring design justified against seasonal and hydrostratigraphic variability;
- separate consideration of superficial/perched and upper-bedrock groundwater, with controls and off-site water receptors selected from the conceptual model;
- high-time-resolution air and methane monitoring during material phases, integrated with meteorology, LDAR and operational logs;
- a surveyed and photographic baseline of landform, drainage and surface condition;
- a single incident and complaint architecture with time-stamped data preservation, cross-domain escalation and model-revision criteria;
- publication of the approved PO 01, PO 05, PO 06 and PO 08 documents, and a reasoned opportunity for review where their contents materially alter the assessed risk envelope;
- defined post-operation and post-abandonment monitoring duration, stop criteria and reopening criteria.
- a complete process-flow and emissions diagram covering drilling returns, shakers, mud tanks, degassing/separation, all vents, scrubbers, storage, flare and relief points, with a closed-system presumption or source-specific BAT justification;
- whole-site and event-specific air assurance linking actual source composition, high-time-resolution measurements, continuous meteorology, flare status and dispersion reconstruction;
- a site-specific seismic monitoring performance specification, including baseline, network geometry, magnitude completeness, location uncertainty, ground-motion coverage, real-time response and trailing-event rules;
- named off-site waste receivers, representative waste acceptance and treatability evidence, cradle-to-grave mass reconciliation and accounting for treatment residuals and final discharge;
- clean/dirty zoning and a controlled vehicle/mobile-equipment decontamination system with contained, classifiable wash water and incident-triggered quarantine.

# Contents

1. Purpose, questions and methodology
2. Site and application architecture
3. Applicable legal and technical framework
4. Summary concordance: standards, submission and gap
5. Groundwater and hydrogeological monitoring
6. Surface water, drainage and receiving environment
7. Site condition, soil, ground movement and ecological observations
8. Air quality, methane, flare performance and odour
9. Waste, chemicals, mining-waste facility and NORM
10. Well integrity, faulting, fracture control and induced seismicity
11. Noise and vibration
12. Accident management, complaints and cross-domain escalation
13. Restoration, closure, aftercare and permit surrender
14. Ranked gap register
15. Proposed permit-condition schedule
16. Conclusions
Appendix A. Detailed standards concordance
Appendix B. Application and permit document inventory
Appendix C. Legal, regulatory and technical references
Appendix D. Definitions and evidential language
Appendix E. Incident-derived failure-mode review

# 1. Purpose, questions and methodology

## 1.1 Purpose

This report evaluates whether the environmental monitoring and assurance architecture proposed for Cloughton 2 is adequate when tested against the relevant UK legal framework, Environment Agency guidance, EU-derived regulatory principles, current European comparator standards and internationally recognised technical practice. The assessment is designed to identify precisely what is present, what is deferred, what is scientifically under-specified and what safeguard would close each gap.

## 1.2 Questions

1. What environmental information and monitoring does the application actually contain?
2. Which requirements are binding under UK law or the draft permit?
3. Which EU standards remain binding only through domestic implementation, and which current EU measures are merely comparative?
4. Can the proposed methods detect the relevant event type at the required spatial and temporal scale?
5. Can the resulting evidence support attribution, trend analysis, trigger decisions and reconstruction after an event?
6. Do monitoring domains operate as one system, or can coincident signals be assessed and closed separately?
7. What proportionate permit condition, plan amendment or pre-operational evidence would close each material gap?

## 1.3 Evidence hierarchy

The following hierarchy was applied. Higher tiers control where sources conflict:

| Tier | Source class | Role |
|---|---|---|
| 1 | Draft permit and draft Environment Agency decision | Primary permit-specific evidence |
| 2 | Applicant technical submissions and incorporated operating techniques | Primary application evidence |
| 3 | Current UK legislation and official regulator guidance | Binding law or authoritative regulatory interpretation |
| 4 | Official EU legislation and Commission guidance | EU-derived context or current comparator |
| 5 | ISO/EN and equivalent internationally recognised technical standards | Methodological benchmark |
| 6 | Prior independent analysis, including the existing objection and monitoring-architecture papers | Issue identification and analytical framing only; not used as proof of a legal or site-specific fact |

## 1.4 Gap test

A finding was recorded only where the documents support one or more of the following:

- Completeness gap — a decision-relevant document, parameter, design, threshold or location is absent or deferred.
- Coverage gap — relevant receptors, strata, wind sectors, time periods or lifecycle phases are outside the monitoring envelope.
- Resolution gap — the averaging period, sampling frequency or detection limit cannot answer the stated event question.
- Attribution gap — controls, tracers, isotopes, meteorology or operational correlation are insufficient to distinguish plausible sources.
- Integration gap — signals remain in separate plans, regulators or thresholds without mandatory cross-domain review.
- Revision gap — no explicit trigger requires the conceptual model or monitoring design to be reconsidered when observations depart from prediction.
- Closure gap — monitoring duration, cessation tests, data preservation or reopening criteria are undefined.

### 1.5 Grading

| Grade | Meaning |
|---|---|
| Critical | A decision or activity should not proceed until resolved because the missing element defines the risk or baseline against which compliance will be judged. |
| High | Materially limits detection, attribution, public review or the ability to demonstrate environmental protection. |
| Moderate | Weakens assurance but may be resolved through a defined plan, additional monitoring or clarification. |
| Low | Presentational, reporting or optimisation issue with limited effect on core risk evaluation. |
| Strength | A control or assessment that meets or substantially follows recognised practice and should be preserved. |

## 2. Site and application architecture

### 2.1 Proposed activities

The proposal is for construction of a temporary wellsite, drilling and logging of the Cloughton-2 appraisal well, well completion and clean-up, an extended well test and, if required, a low-volume proppant squeeze followed by restoration or further authorised development. The conceptual well is deviated to target Carboniferous formations at approximately 2.3 km true vertical depth and approximately 3.0 km measured depth. The stimulation is described as 300–500 m³ per stage in the decision document, with up to four stages, while the Waste Management Plan contains larger retained-fluid and spatial-volume estimates that must be read with care because the documents may be referring to different scenarios or definitions. (A1, pp. 26–27; A9, pp. 23–25, 36–38; A11, p. 12)

The draft permit combines a mining-waste operation, a deep subsurface mining-waste facility, an installation activity for flaring, and groundwater activities. It imposes pre-operational conditions for groundwater monitoring, updated management plans, LDAR, surface-water controls, the Hydraulic Fracture Plan and final target depths. (A2, pp. 15–18)

### 2.2 Receptors and hydrogeological setting identified by the applicant

- Burniston Beck lies approximately 115 m southwest of the site entrance; an additional drainage ditch lies near the south-east boundary and discharges to the beck.
- A pond is approximately 100 m southwest of the site centre, another is around 80 m north of the entrance, and at least 20 smaller ponds are mapped within 3 km.
- Seven springs are mapped within 3 km; the nearest is approximately 250 m northeast and active springs are cited as evidence of perched groundwater.
- Superficial glacial diamicton is mapped as Secondary undifferentiated/unproductive, but sand and gravel pockets can hold perched groundwater. Jurassic bedrock is a Secondary A aquifer and is conceptualised as multilayered with restricted vertical movement.
- **The site is seasonally waterlogged and the HIA recognises that winter waterlogging is possible.**

Sources: A4, pp. 4–5, 11–14, 22, 33–34; A5, pp. 20–21.

### 2.3 Monitoring and control layers already present

| Layer | Submitted provision | Assessment |
|---|---|---|
| Containment | Welded HDPE liner, perimeter ditch, secondary containment, spill response and site designed to retain water before overflow. | Preserve; verify construction quality and integrity criteria. |
| Groundwater | Three proposed boreholes; monthly three-month baseline; weekly drilling/testing sampling; independent sampling and laboratory analysis. | Useful foundation, but design and scope need expansion/justification. |
| Air | Baseline and flare-period passive monitoring for multiple pollutants; weather station during sampling; flare emission limits and process monitoring. | Useful for averages and compliance, not transient-event reconstruction. |

| Layer | Submitted provision | Assessment |
|---|---|---|
| Noise | Extended baseline, multiple positions, weather screening, BS 4142/BS 5228 assessment, source contribution and mitigation review. | Comparatively strong technical submission. |
| Odour | On-site sniff testing, release-point investigation, accredited laboratory sampling, action log, complaint forms and optional resident diaries. | Strongest complaint/investigation plan in the package; needs cross-domain linkage. |
| NORM | Gamma-spectrometric analysis of formation/flowback water, competent RPS/RWA and RSR disposal route. | Appropriate operational waste control; no receiving-environment baseline. |
| Fracture/seismic | PO 08 requires fault/stress analysis, fracture controls, local seismic monitoring and post-fracture reporting. | Material safeguard, but deferred and not yet reviewable. |

### 2.4 Statutory basis for proceeding despite the England fracking moratorium

The Government's presumption against issuing further hydraulic fracturing consents in England has applied, with one brief interruption between September and October 2022, since November 2019. That presumption is given effect through the well-consent safeguards at sections 4A and 4B of the Petroleum Act 1998, inserted by section 50 of the Infrastructure Act 2015, which restrict "associated hydraulic fracturing" only where an operation involves, or is expected to involve, the injection of more than 1,000 m³ of fluid at any stage or more than 10,000 m³ in total. (UK17)

The stimulation proposed for Cloughton 2 is described as a proppant squeeze of 300–500 m³ per stage across up to four stages, an estimated maximum total of approximately 2,000 m³ (A1, pp. 26–27; A9, pp. 23–25, 36–38). Both figures fall below the statutory thresholds. The operation therefore does not meet the legal definition of "associated hydraulic fracturing," is not subject to the ministerial hydraulic fracturing consent regime, and falls outside the scope of the current moratorium as a matter of law, notwithstanding descriptions of the technique in press and public commentary as small-scale or "stealth" fracking.

This report takes no position on where that statutory boundary should be drawn. It records, for the purpose of assessing this application, that the volume threshold is the sole legal determinant of whether the moratorium applies, and that it does not itself vary with local fault geometry, in-situ stress, proximity to mapped faults or induced-seismicity history. Independent peer-reviewed analysis has identified the same volume thresholds as capable of allowing operations with materially similar geomechanical characteristics to proceed outside the moratorium's scope (ACAD1). The practical consequence for this application is that the statutory classification of the stimulation as non-fracking does not, without more, establish that the fault-interaction and induced-seismicity risks addressed in Section 10 are proportionately reduced. The adequacy of the site-specific seismic monitoring architecture required under PO 08 (Findings FS-1 to FS-4) should accordingly be assessed on its technical merits, independent of the regulatory label attached to the stimulation volume.

## 3. Applicable legal and technical framework

### 3.1 Binding UK framework

| Instrument | Class | Core relevance | Application to this audit |
|---|---|---|---|
| Environmental Permitting (England and Wales) Regulations 2016 | A | Controls the installation, mining-waste operation, groundwater activities and radioactive-substances activities. Schedule 22 requires prevention of hazardous inputs and limitation of non-hazardous pollutants, subject to specified exclusions. | Directly binding through the permit and regulations. |
| Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 | A/C | Requires river-basin environmental objectives, including prevention of deterioration and protection of groundwater and surface water. | Binding domestic implementation of WFD principles. |
| Industrial Emissions Directive Article 22 as implemented by EPR | A/C | Requires a baseline report where relevant hazardous substances may contaminate soil or groundwater, so condition at cessation can be compared with baseline. | The decision expressly finds the submitted report incomplete and uses PO 01. |

| Instrument | Class | Core relevance | Application to this audit |
|---|---|---|---|
| Mining Waste Directive as implemented by EPR Schedule 20 | A/C | Requires a waste-management plan and controls to prevent or reduce adverse effects on water, air, soil, fauna, flora and landscape during operation and after closure. | Applicable to the extractive wastes and deep facility; Category A duties do not automatically apply. |
| DCR 1996 and Borehole Sites and Operations Regulations 1995 | A | Well design, construction, examination, reporting and integrity throughout the lifecycle. | HSE/NSTA roles complement, but do not replace, environmental detectability. |
| Radioactive substances regulation under EPR Schedule 23 | A | Controls accumulation and disposal of NORM waste from oil and gas production where in scope. | Operational waste controls are required before production/testing gives rise to NORM waste. |

## 3.2 Environment Agency and UK technical guidance

- The EA onshore oil and gas monitoring guidance requires baseline monitoring before operations, monitoring through the operational lifecycle, and decommissioning/post-abandonment monitoring before permit surrender. Technique and frequency should follow source–pathway–receptor risk and lifecycle changes. (UK3)
- The earlier sector guidance describes three sets over three months as a basic minimum, but expressly says more samples are required where seasonal variations need to be identified. This makes three months a floor, not a presumption of representativeness. (UK4)
- EA research on statistical significance frames monitoring design around where, what, how often and for how long, and emphasises that survey design must match the statistical question, environmental variability and the ability to attribute change. (UK5)
- EA groundwater-protection policy expects the hydrogeological assessment to consider all groundwater that could be affected, including groundwater-bearing strata at depth, with mitigation proportionate to sensitivity and associated receptors. (UK11)
- EA ambient-air guidance distinguishes time-integrated and real-time methods and requires method performance, quality assurance and appropriate monitoring technique. MCERTS provides the quality framework for instruments, people and laboratories. (UK6–UK7)
- EA management-system guidance states that an accident prevention and management plan is needed for incidents or events that could cause pollution or permit non-compliance, with identified causes, consequences, prevention and response. (UK8)

## 3.3 European standards and comparative practice

The following distinctions are essential:

- Directive 2010/75/EU and the Water Framework/Groundwater framework remain relevant where implemented through UK domestic law. The domestic regulation is the binding route.
- Commission Recommendation 2014/70/EU is non-binding and formally directed at high-volume hydraulic fracturing. Cloughton is described as a low-volume proppant squeeze. The Recommendation is therefore used only as a comparator for baseline, disclosure, monitoring and risk-management principles.
- Regulation (EU) 2024/1787 on methane emissions is current EU law but does not directly bind this UK site. Its measurement, verification, LDAR, repair-verification and venting/flaring provisions are evidence of contemporary European methane practice.
- Current EU groundwater policy continues to require prevention/limitation of pollutant inputs, trend detection and reversal. This is consistent with, but does not add directly enforceable duties beyond, the UK domestic framework for this permit.

## 3.4 Internationally recognised technical practice

| Standard | Subject | Relevance |
|---|---|---|
| ISO 5667-1:2023 | Sampling-programme design and sampling techniques. | Objectives, representativeness, locations, timing, QA. |
| ISO 5667-11:2009 | Groundwater sampling. | Planning, sampling, handling and contamination assessment. |
| ISO 5667-22:2010 | Design and installation of groundwater monitoring points. | Representative samples; installation materials and screen design. |
| ISO 5667-3:2024 | Preservation and handling of water samples. | Chain of custody, stability and storage. |

| Standard | Subject | Relevance |
|---|---|---|
| ISO 18400-101:2017 | Framework for soil sampling plans. | Objectives, locations, depths, samples and decision rules. |
| ISO 18400-203:2018 | Investigation of potentially contaminated sites. | Baseline/site investigation strategy and representative sampling. |
| ISO/IEC 17025:2017 | Laboratory competence. | Impartiality, method validation, technical competence and reliable results. |
| ISO 16530-1:2017 | Well integrity lifecycle governance. | Hazards, barriers, handover, intervention and abandonment. |
| EN 15446 or equivalent | Measurement of fugitive VOC emissions from equipment leaks. | Explicitly required by draft PO 05 for LDAR. |
| BS 4142 and BS 5228 series | Industrial/construction noise assessment. | Substantially applied in the NVIA. |

## 4. Summary concordance: standards, submission and gap

| Domain | Benchmark | Current submission | Grade | Required closure |
|---|---|---|---|---|
| Baseline report | IED Article 22 / EPR; EA sector guidance | SCR submitted, but soil plan and groundwater parameters remain future work; EA states Article 22 baseline absent. | Critical | Complete and approve baseline before ground disturbance; publish approved version. |
| Groundwater duration | EA basic minimum 3 months; more where seasonality matters; EA statistical guidance | Three monthly rounds before well construction. | High | 12 months or documented statistical justification that shorter period captures annual range. |
| Hydrostratigraphic coverage | EA groundwater protection; ISO 5667-22 | Three upper-bedrock boreholes; superficial perched water acknowledged but not separately monitored. | High | Nested/multilevel or separate superficial and bedrock installations where CSM supports them. |
| Groundwater analytes and triggers | PO 01; ISO 5667; ISO/IEC 17025 | “Extensive range” and contamination trigger not defined in application; all deferred. | High | Fixed analyte/tracer list, LOQs, QA/QC, statistical thresholds and investigation ladder. |
| Surface-water receptors | Risk-based WFD/EPR objectives; ISO 5667 | Containment-ditch sampling only; no off-site receptor network. | High | Control and potentially affected points at beck, ditches, ponds/springs, with event triggers. |
| Air baseline placement | EA ambient-air guidance; monitoring objective and meteorology | Two locations chosen later by operator consultant; no stated wind-sector/receptor validation. | Moderate | Predefined rationale using wind sectors, receptors, background and source geometry. |
| Transient methane/VOC detection | EA monitoring technique; EU Methane Regulation comparator | 4-week passive tubes, 1-minute grabs, 30-minute mobile CH4 walk. | High | Continuous/near-real-time CH4 and selected VOC/H2S during material phases; operational correlation. |
| LDAR | PO 05; EN 15446; EU methane comparator | Plan deferred to PO 05. | Moderate | Source inventory, survey frequency, instrument thresholds, repair and verification deadlines. |
| Flare verification | Permit ELVs; BAT/process monitoring | Annual stack test; none if flare operates <10% of year; process parameters continuous. | Moderate | Commissioning/first-use and material gas-composition tests irrespective of annual operating fraction. |
| Fault and fracture model | PO 08; NSTA/HSE; ISO 16530-1 | Material model and monitoring details deferred. | Critical | Approve and disclose HFP before stimulation; assumptions, uncertainty and revision rules explicit. |
| Accident management | EA management-system guidance | No dedicated AMP; controls dispersed across documents. | High | One controlled AMP linking scenarios, monitoring, data preservation, notifications and recovery. |
| NORM attribution | EPR Schedule 23; EA OOG guidance | Operational gamma-spectrum analysis and RSR route; no receiving-environment baseline. | Moderate | Proportionate pre-disturbance gamma/soil/water controls and event-triggered verification. |
| Ground condition | Article 22/site condition principles; ISO 18400 | Soil analysis proposed; no repeatable topographic/drainage/crack/ponding baseline. | High | Survey control, fixed photography and drainage/settlement observations across lifecycle. |
| Noise event response | BS 4142/BS 5228; planning conditions | Strong baseline; complaint monitoring may occur up to 48h later and previous monitoring may be treated as evidence. | Moderate | Rapid capture and operation-specific correlation; prior unmatched monitoring not dispositive. |

| Domain | Benchmark | Current submission | Grade | Required closure |
|---|---|---|---|---|
| Odour response | EA H4 principles | Detailed sniffing, sampling, action log and diary provisions. | Strength / Moderate | Preserve; add response times, public route and cross-domain correlation. |
| Cross-domain escalation | EA EMS; ISO 14001-type corrective-action principles | No common event ID or mandatory synthesis across air, water, well, seismic, noise and complaints. | High | Single event protocol with data hold, multi-domain review, closure and reopening tests. |
| Aftercare | EA lifecycle monitoring; permit surrender | Post-decommissioning plan required by PO 01, but duration and cessation criteria not defined. | High | Risk-based minimum period, stability tests, trend criteria and reopening provisions. |
| Air - source completeness | BAT/source inventory must cover all material emissions | Waste Gas Plan focuses on production testing; drilling-return gas system not identified | Require complete process/emissions diagram and closed/captured system justification | High |
| Air - event geometry | Monitoring must be capable of intercepting and reconstructing the event | Two fixed sites, passive averages; meteorology not integrated across whole operation | Continuous meteorology, whole-site/event methods and event-specific dispersion reconstruction | High |
| Waste chain | Waste duty of care, BAT and receiving-facility suitability | Generic permitted receiver; treatability, residual fate and mass reconciliation absent | Named receiver, acceptance/treatability, residual and final-discharge mass balance | High |
| Mobile transfer | Containment must address credible carriers across the boundary | Wheel wash is a dust control; no chemical/NORM decontamination architecture | Clean/dirty zoning, contained decontamination, incident quarantine and residue classification | High |
| Seismic monitoring | HFP and recognised induced-seismicity monitoring practice | Local monitoring promised; performance and geometry unspecified | Baseline, surface/downhole or equivalent, ground motion, real-time/trailing response and publication | Critical to stimulation |

# 5. Groundwater and hydrogeological monitoring

## 5.1 What the application provides

The HIA compiles regional mapping, borehole records, a site walkover and operator information. It recognises two broad groundwater domains: superficial deposits that may include perched water in sand/gravel pockets, and a multilayered Jurassic bedrock aquifer. Groundwater direction is inferred eastward from regional mapping and section, rather than established from site-specific heads. (A4, pp. 2–3, 11–14, 33–34)

The base monitoring scheme comprises three shallow boreholes outside the bund: one described as upstream and two downstream. Each is proposed as a 50 mm standpipe slotted from 0.5 m above the phreatic surface to 0.5 m from the base. Baseline sampling is monthly for three months, weekly during drilling and testing, then monthly. Samples are to be collected by an independent third party and analysed by an independent laboratory. (A4, pp. 26, 28–29)

The draft permit does not yet fix the borehole construction, monitored formations, parameters, sampling method, frequency, interpretation method or trigger levels. PO 01 requires those details and post-decommissioning monitoring before activities commence. (A2, pp. 15–16)

## 5.2 Strengths

- Monitoring starts before well construction and becomes weekly during drilling/testing.
- Independent sampling and laboratory analysis are proposed.
- The layout attempts to include one upgradient and two downgradient points.
- PO 01 explicitly requires trigger levels, interpretation methods and investigation of potentially erroneous results.
- The HIA cites BS ISO 5667-11 for groundwater sampling.

## 5.3 Gap GW-1 — baseline duration and representativeness

Three monthly samples over three months are a recognised basic minimum in the EA sector guidance; they are not automatically a representative seasonal baseline. The same guidance requires more sampling where seasonal variation matters. Here, the applicant describes seasonally waterlogged soils, potential perched aquifers and active springs. The monitoring period could fall entirely within one recharge state. A statistically stable mean over three observations does not establish the annual range, lagged rainfall response, episodic recharge or drought condition. (A4, pp. 22, 28, 33; UK4–UK5)

### Finding GW-1 — High

The application does not demonstrate that three months can characterise the site's annual hydrochemical and hydraulic variability. The weakness is not failure to meet the published basic minimum; it is failure to justify that the minimum is sufficient for this site.

Required closure: at least one hydrological year, or a shorter period only where existing site-specific data and a written statistical analysis demonstrate that the selected window captures relevant high, low and transitional groundwater conditions. Disturbance that could alter drainage, groundwater recharge or soil chemistry should not precede the baseline.

## 5.4 Gap GW-2 — superficial/perched groundwater outside the network

The HIA acknowledges that sand and gravel pockets within the diamicton can hold perched groundwater and cites nearby springs and borehole evidence. Yet the conclusion states that the three boreholes will determine conditions in the upper bedrock aquifer. Without a separate superficial installation, a shallow release or altered recharge pathway could be attenuated, diluted or delayed before reaching the monitored bedrock interval. (A4, pp. 25, 33–34)

### Finding GW-2 — High

The network is not shown to monitor every groundwater domain that the applicant itself identifies as potentially active. This is a coverage gap against the EA expectation that all groundwater that could be affected is considered.

Required closure: use site investigation and head data to determine whether separate superficial/perched and bedrock monitoring is required. Where vertical gradients or perched lenses exist, use nested or multilevel installations rather than assuming one screened interval represents the system.

## 5.5 Gap GW-3 — long-screen mixing and unresolved borehole design

A screen extending from above the phreatic surface nearly to the borehole base may integrate water from multiple beds. In a multilayered aquifer this can smooth vertical differences, create a pathway within the installation and make source attribution more difficult. ISO 5667-22 requires monitoring-point design to preserve sample integrity and obtain

representative groundwater. The risk cannot be resolved until depth, strata, seals and screen lengths are fixed under PO 01. (A4, pp. 13–14, 28; ISO3)

Required closure: provide drilling logs, completion diagrams, seal intervals, development methods, hydraulic testing and a rationale for screen length. Short discrete screens or multilevel completions should be used where needed to distinguish horizons.

### 5.6 Gap GW-4 — analytes, detection limits, tracers and triggers

The HIA refers to an “extensive range” of parameters but does not list them. The permit deliberately leaves parameters, frequency, interpretation and trigger levels to PO 01. The chemical inventory contains substances with hazard classifications, including biocides, caustic materials, surfactants, crosslinkers, oxidants, silica-bearing products and proprietary components. A generic major-ion suite would not necessarily detect or attribute all relevant releases. (A4, p. 28; A11, pp. 1–12; A2, p. 15)

Required closure: a chemical-to-monitoring crosswalk identifying indicator parameters, specific constituents where analytically feasible, dissolved methane and provenance tools where relevant, field parameters, major ions, metals, organics, radionuclides, laboratory methods, method detection limits, blanks, duplicates, calibration, data validation and control charts. Trigger levels must include trend/persistence and multivariate change, not only single-sample exceedance.

### 5.7 Gap GW-5 — conceptual-model revision

The HIA repeatedly converts predicted containment into negligible residual risk. It states that no hydraulic connectivity is anticipated between superficial and bedrock aquifers, that mud cake precludes fluid interaction, and that geology/casing will ensure no fluid interchange. These may be reasonable design hypotheses; they are not observations. A monitoring system should include explicit conditions under which those hypotheses are reconsidered. (A4, pp. 13–14, 26–27, 34)

Required closure: a model-breach register. Unexpected head response, chemistry, gas, losses/gains, new seepage, repeated sub-threshold trends or spatially coherent off-site observations should trigger review of the conceptual model, network and monitoring frequency.

## 6. Surface water, drainage and receiving environment

### 6.1 What the application provides

The Surface Water Management Plan is primarily a containment-water plan. Surface runoff is retained in the lined perimeter ditch, tested for waste classification, and removed by tanker; no routine discharge to surface water is proposed. Field pH, conductivity and temperature are recorded, with laboratory parameters selected according to operational risk. (A6, pp. 13–18)

This is a meaningful pollution-prevention control. It is not an ambient receiving-environment monitoring programme.

### 6.2 Gap SW-1 — no off-site receptor network

Burniston Beck, two nearby drainage ditches, ponds and springs are identified in the HIA/SCR, but none is assigned a baseline, control or operational monitoring point. The system can classify water inside the site and respond to an obvious spill; it cannot itself determine whether an unobserved pathway, overtopping episode, liner defect, construction runoff or altered drainage produced an off-site response. (A4, pp. 4–5, 33–34; A5, p. 20; A6, pp. 17–18)

**Finding SW-1 — High**

The submitted plan manages contained water but does not monitor the receiving environment. This is not proof that an off-site programme is legally mandatory in every case; it is a clear limitation on what the operator’s evidence can demonstrate.

Required closure: select at least one background/control and one potentially affected location in Burniston Beck and relevant ditches. Include nearby pond/spring sites where the conceptual model supports a pathway. Fix coordinates, flow state, analytes, sediment criteria and access arrangements before construction. Permanent near-real-time monitoring at model-derived locations represents the strongest achievable form of assurance for this receptor network.

### 6.3 Gap SW-2 — no event-triggered monitoring

Routine ditch sampling is not tied to rainfall intensity, overtopping risk, suspected liner failure, a fluid-loss anomaly, a public report, new ponding, sheen, bubbling, fish/wildlife effects or a coincident groundwater change. Transient events can disappear before the next scheduled visit.

Required closure: defined event triggers, response times, grab and composite methods, chain of custody, upstream/downstream pairing, photographs, field meters, sediment where appropriate, and preservation of rainfall, operational and tank/ditch records.

### 6.4 Gap SW-3 — hydrology and drainage change

The HIA recognises that site levelling can change surface gradients and cause waterlogging, but proposes no specific waterlogging mitigation because the period and volumes are anticipated to be small. The submission does not define pre-construction ditch levels, culvert condition, flow paths, pond levels or photographic stations. (A4, pp. 22, 25) HIA already recognises seasonal waterlogging is possible. Climate change increases the likelihood of extreme weather events, including above average precipitation.

Required closure: a drainage-condition baseline and inspection plan before earthworks, after major rainfall, during each phase transition and before restoration sign-off. The baseline should include calculations of expected rainfall that account for emerging climate science on regional precipitation trends.

## 7. Site condition, soil, ground movement and ecological observations

### 7.1 Article 22 and the submitted Site Condition Report

The Environment Agency states that the submitted Site Condition Report does not include the Article 22 baseline report. The SCR itself says soil sampling and a Ground Investigation Report will be undertaken later and used as the baseline. It contains no final sampling grid, depth, analyte list, method, detection limit or statistical comparison design. (A1, pp. 25–26; A5, pp. 33–34)

**Finding SC-1 — Critical**

The reference condition against which cessation and permit surrender will be judged is not presently complete. PO 01 addresses groundwater, but the draft condition should be checked to ensure the full Article 22 soil and groundwater baseline is completed, not merely three months of groundwater sampling.

### 7.2 Gap SC-2 — soil sampling design

ISO 18400-101 requires the sampling plan to state what samples are taken, how and from where, in a manner capable of answering the investigation objective. The current proposal does not identify the active area, cellar, chemical/fuel storage, drainage ditch, cut/fill zones, control field locations, depths, replicates or relevant hazardous substances. (ISO4–ISO5)

Required closure: a risk-zoned soil and soil-gas plan linked to the chemical inventory and future restoration comparison. Include reference/control locations, coordinate precision, sample depths, QA/QC, archived samples where appropriate, and decision rules for material removal or remediation.

### 7.3 Gap SC-3 — physical ground and surface condition

Chemical soil sampling does not capture settlement, differential movement, cracks, camber change, altered drainage, persistent wet ground, ponding, seepage, erosion or vegetation stress. No generic rule requires LiDAR or InSAR at every temporary wellsite, but a proportionate repeatable topographic and photographic record is inexpensive and materially improves later attribution.

Required closure: establish surveyed benchmarks outside the works, a pre-construction topographic surface, fixed georeferenced photographs and a surface-condition register. Repeat after construction, before/after stimulation, after major incidents or reported change, before restoration and during aftercare.

### 7.4 Ecological and agricultural observations

The air-quality assessment models designated habitats and the HIA identifies water receptors, but there is no route for an observation such as vegetation stress, fish/wildlife mortality, unusual sediment or altered pond ecology to trigger integrated sampling. The appropriate response is not routine intensive ecological monitoring; it is a defined event pathway tied to water, soil, air and operational data.

## 8. Air quality, methane, flare performance and odour

### 8.1 Air-quality assessment and baseline provision

The AQIA uses dispersion modelling, conservative screening assumptions and statutory/EA assessment criteria for combustion emissions, traffic, fugitive releases and ecological receptors. It transparently discusses several uncertainties. For fugitive natural gas it applies annual emission factors as a continuous uniform release over the 273-day programme; that is conservative for total mass and annual average impact, but it is not a model of an episodic leak or short peak. (A8, pp. 34–35, 45–46, 91–92)

The monitoring plan proposes three baseline rounds at two locations, selected during the consultant's first visit. Methane is measured by a one-minute grab and a 30-minute mobile perimeter walk. BTEX, VOCs, NOx, $H_2S$, $SO_2$ and ozone use four-week passive tubes; dust uses a four-week deposition gauge. Laboratory reports are expected within 20 working days after collection. (A7, pp. 15–18)

## 8.2 Strengths

- Multiple pollutant classes are included rather than $NO_2$ alone.
- Baseline and flare-period rounds are proposed, with a post-flare round.
- A weather station is provided during sampling.
- The AQIA employs sensitivity analysis and generally conservative assumptions for long-term impact.
- PO 05 requires an LDAR plan using EN 15446 or equivalent.
- The draft permit requires continuous flare feed flow, combustion temperature and methane monitoring, plus monthly composition analysis.

## 8.3 Gap AQ-1 — location selection and representativeness

The two monitoring locations are TBC and delegated to the operator's consultant. No explicit rule requires one background station, one downwind receptor station, sector rotation, open-path geometry or validation against local wind roses and terrain. The monitoring report may document the choices after installation, but the design objective is not predetermined. (A7, p. 15)

Required closure: a written siting protocol based on source geometry, prevailing and stable low-wind conditions, nearest receptors, background sources, topography, access/security and data completeness. Meteorology should be continuous for the operational period, not only while passive samples are deployed.

## 8.4 Gap AQ-2 — transient release detectability

Four-week diffusion tubes measure time-weighted averages. A 30-minute mobile walk provides a brief spatial snapshot. Neither can reconstruct a release lasting minutes or hours, determine its peak, or show whether it coincided with a valve operation, pressure anomaly, flare instability or complaint. The AQIA itself notes that short odour peaks can be much higher than hourly averages. (A7, pp. 15–18; A8, pp. 91–92)

### Finding AQ-2 — High

The air plan is suitable for average baseline/compliance screening but not for rapid detection and reconstruction of intermittent methane, VOC or $H_2S$ events.

Required closure: continuous or near-real-time methane monitoring during drilling, completion, clean-up, stimulation and testing; high-time-resolution $H_2S$/total VOC where risk justifies; continuous meteorology; alarm/event data preservation; periodic speciated sampling; and correlation with LDAR, tank, separator, flare and well-operation logs. MCERTS-certified or demonstrably equivalent equipment should be used where available and appropriate.

## 8.5 Gap AQ-3 — delayed reporting and trigger logic

A passive sample may be retrieved after four weeks and reported up to 20 working days later. The plan does not set ambient trigger levels, escalation rules, duplicate/field-blank frequencies for all media, data-completeness objectives or a rapid response when a live instrument detects an anomaly. (A7, pp. 17–18)

Required closure: separate compliance, action and investigation thresholds; immediate notification for high readings; trend/persistence rules; data validation status; and a public-facing summary without waiting for the end of a long sampling round.

## 8.6 Gap AQ-4 — flare verification

The draft permit sets annual periodic emission monitoring for NOx, CO and total VOC, but says monitoring is unnecessary where the flare operates for less than 10% of a year. The project is intrinsically short-duration, so the exemption could mean no direct stack test during the appraisal episode. The updated Waste Gas Management Plan describes the selected shrouded flare as having reduced or slightly lower combustion efficiency than an enclosed flare, while expecting performance above 98% and acknowledging that efficiency can be more difficult to regulate. Continuous feed flow, temperature, methane and monthly composition are valuable process controls, but nominal efficiency and operating parameters are not direct verification of destruction and pollutant performance during commissioning, unstable flow, changing composition, low-flow operation or flame loss. (A2, pp. 19–21; A10, pp. 20–26, 34–40)

Required closure: first-use/commissioning and representative phase-specific testing regardless of annual operating fraction; continuous flame/pilot status, inlet flow, methane, temperature and relevant pressure records; actual feed-gas composition and calorific-value confirmation; quantified cold-vent records; automatic alarm/hold rules; and additional verification after material feed-gas, flow-range or operating changes.

## 8.7 Gap AQ-5 - drilling-return gas handling and source completeness

The updated Waste Gas Management Plan states that its BAT assessment is for the Production Testing Phase. The indicative drilling layout identifies a shaker tank, settling tank, mix tank, cuttings tank and associated mud equipment, but does not identify a degasser, mud-gas separator, enclosed return system, gas vent or route to abatement. The well-testing layout separately identifies a gas scrubber and vent, gas knock-out and shrouded ground flare. The Environmental Risk Assessment relies on overbalanced drilling mud to prevent gas reaching the surface. That is a well-control assumption, not a complete description of how gas entrained in routine drilling returns would be detected, separated, sampled, captured, treated or discharged. The documents do not prove that an open degasser will be used; they leave the drilling-return emissions architecture materially under-specified. (A3; A10, p. 20; A15)

Required closure: a single process-flow and emission-point diagram for all drilling and testing phases, identifying shakers, active and trip tanks, degassing and mud-gas separation, vents, reliefs, scrubbers, knock-outs, flare connections and emergency routes. Gas-bearing returns and hydrocarbon-bearing tanks should be closed or captured by default; any open equipment should receive a source-specific BAT justification, actual composition and release-rate assessment, methane/H2S/radon screening where relevant, and synchronised operational and emissions logging.

## 8.8 Meteorology, monitoring geometry and event reconstruction

The AQIA already uses ADMS dispersion modelling; the gap is not an absence of modelling. It is the separation between an assumed source term, sparse time-averaged ambient monitoring and the actual meteorology at the time of an event. The Environment Agency whole-site methane research treats wind speed, direction, concentration measurements and modelling as one estimation system. Two fixed locations and four-week averages cannot be assumed to intercept or reconstruct every narrow episodic plume. (A7; A8; UK12)

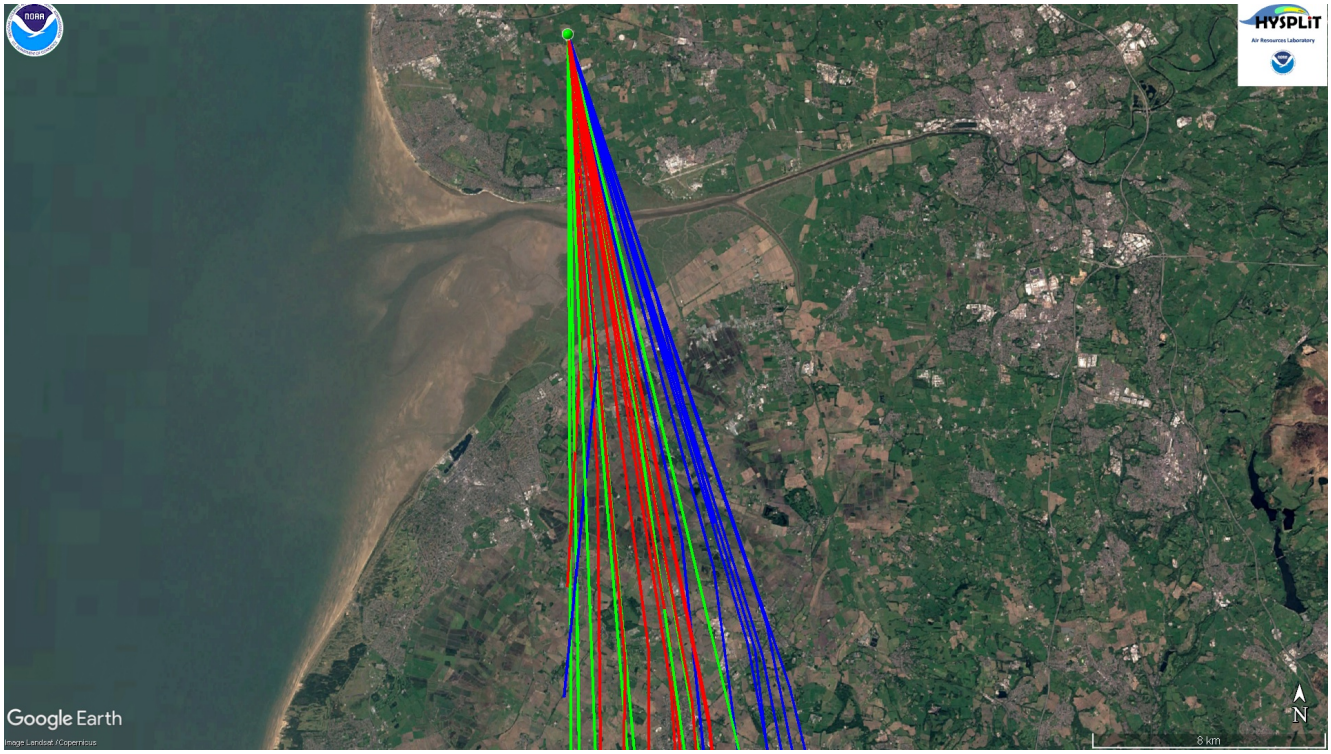


*Figure 1. Representative one-day HYSPLIT trajectory ensemble previously generated from the Preston New Road site. The lines show modelled air-parcel trajectories under the selected meteorological setup; they are not plume boundaries, concentrations, exposure probabilities or deposition contours. Their relevance is illustrative: a release may occupy a relatively narrow receiving corridor on a given day. Source: D. Nye historical NED project archive; NOAA HYSPLIT/Google Earth.*

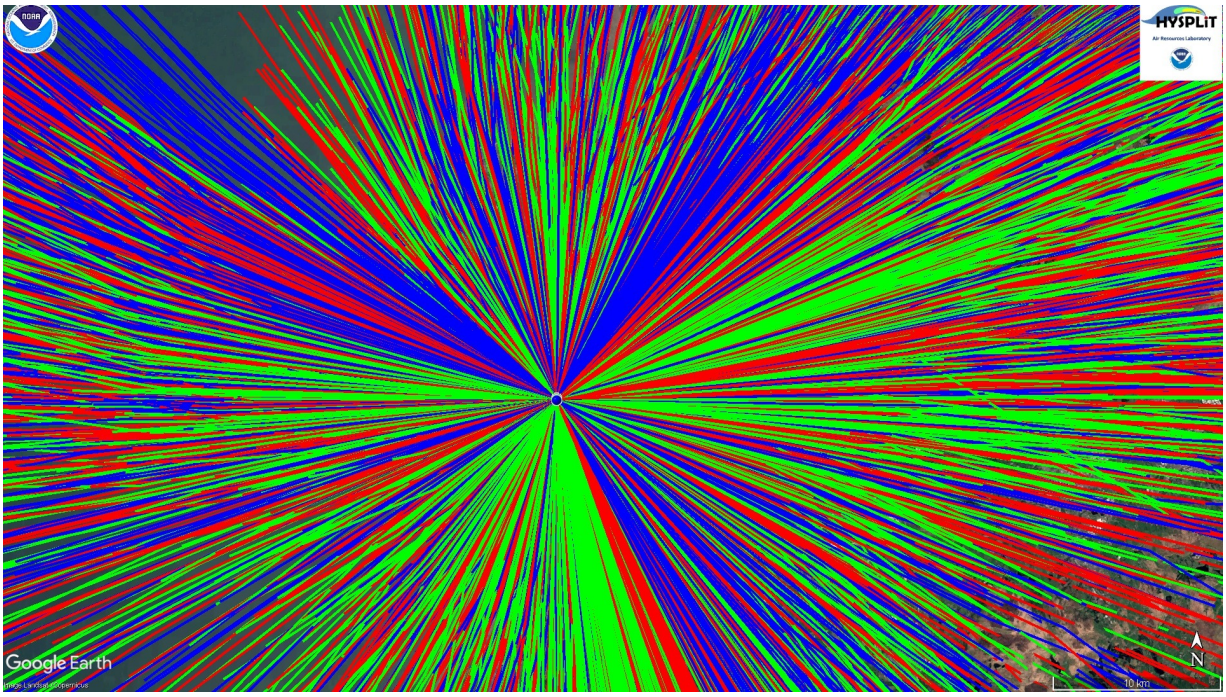


*Figure 2. Composite of daily HYSPLIT trajectory ensembles generated for October 2018 from Preston New Road. The dense radial pattern does not represent cumulative concentration or dose. It illustrates that the downwind receiving sector changes substantially through time, so fixed monitoring locations alternate between downwind, crosswind and upwind conditions. Source: D. Nye historical NED project archive; NOAA HYSPLIT/Google Earth.*

Required closure: continuous site meteorology across all material phases; monitor siting validated against source height, wind sectors, terrain and receptors; whole-site or open-path methods where proportionate; actual source composition and release timing; and event-specific ADMS or HYSPLIT reconstruction after flare failure, cold venting, abnormal gas detection, visible emission, significant odour or other qualifying event. Model output should guide targeted contemporaneous sampling, not substitute for it.

## 8.9 LDAR and current European methane practice

PO 05 is a significant safeguard because it requires a written LDAR plan and EN 15446 or equivalent measurement. The plan is not yet in the consulted package. Current EU methane law is not binding here, but it provides a strong comparator: direct measurement, verification, recurring LDAR, repair deadlines, repair verification, and restrictions on routine venting/flaring. (A2, p. 16; EU5)

Required closure: complete equipment inventory, component-level survey frequencies by risk, quantitative detection threshold, repair times, repair verification, inaccessible-component rules, record retention, mass-emission estimation and reconciliation with ambient observations.

## 8.10 Odour

The Odour Management Plan is a relative strength. It provides steady-state sniff testing, release-point monitoring, point/grab sampling at accredited laboratories, wind and activity records, action logs, complaint forms and resident diaries. (A13, pp. 31–35)

Residual gaps are response time, public access route and integration. “As soon as reasonably practicable” is not a fixed capture window; a short odour may dissipate. The odour event should automatically preserve methane/VOC, meteorology, separator, flare, pressure and operational records and should share the same event identifier used by other monitoring domains.

## 8.11 Greenhouse gas relevance of methane and flare monitoring

The gaps identified above at AQ-2, AQ-5, LDAR (§8.9) and flare verification (AQ-4) are framed as air-quality and event-detectability issues. The same fugitive methane, drilling-return gas and flare-performance uncertainties are also directly relevant to greenhouse gas accounting, because methane has a substantially higher short-term global warming potential than the carbon dioxide produced by its complete combustion. Regulation (EU) 2024/1787 treats direct source measurement, leak detection and repair, and restriction of routine venting and flaring as core methane-mitigation measures; while that Regulation does not bind this site, it is consistent with the Environment Agency’s own emphasis on quantified, verified emissions rather than nominal design performance. (EU5)

No additional monitoring beyond what is already sought at AQ-5, PC-08/C7 and PC-09/C15 is required to achieve this. The point is architectural rather than additive: verified, rather than nominal, source and control performance

carries greenhouse gas significance as well as local air-quality significance, and the same evidentiary chain – actual composition, feed flow, flame status and cold-vent quantification – closes both questions at once.

# 9. Waste, chemicals, mining-waste facility and NORM

## 9.1 Chemical disclosure and environmental monitoring crosswalk

The chemical inventory is substantial and includes product purpose, hazardous constituents, ranges, CAS numbers and hazard statements. It also includes contingency products and several TBC proppant products. Disclosure is therefore more developed than a generic list, but it is not translated into the groundwater, surface-water, soil or air parameter set because that set remains deferred. (A11, pp. 1–12)

Required closure: prior to use, all TBC products and final concentrations must be approved; the final chemical schedule should map each environmentally relevant constituent or proxy to monitoring media, analytical method, detection limit and response threshold. Proprietary identity can be protected where legally justified, but the regulator must retain complete composition and the public record should contain sufficient hazard and monitoring information.

## 9.2 Mining-waste facility and retained fluid

The Waste Management Plan classifies retained proppant carrier fluid as a non-hazardous deep mining-waste facility. It states that 50–70% of fluid may remain and that the final extent will be determined through fracture modelling. The retained-fluid table specifies “Monitoring: None,” while PO 08 requires fracture-control and post-fracture reporting. Direct sampling at depth is impracticable, but “none” is too broad if it excludes pressure, volume, mass-balance, return-fluid chemistry and model reconciliation. (A9, pp. 37–38, 49; A1, pp. 75–76)

Required closure: define indirect monitoring and verification: injected/returned mass balance; stage pressure/rate; losses; flowback recovery; post-fracture geometry; well integrity; formation-water composition; and model revision if observed returns or pressure responses depart from predictions.

## 9.3 NORM controls and baseline

Formation and flowback water are to undergo radionuclide analysis by gamma spectrometry. A Radiation Protection Supervisor and/or Radioactive Waste Adviser is appointed, and waste is routed according to RSR status. A contamination monitoring programme is promised for the wellhead, separator and tanks, with outgoing consignments screened. These are appropriate operational controls. The remaining source question is broader than liquid NORM: representative natural gas is not yet available, and the application does not identify a radon-222 source term or a decision rule for gaseous-radionuclide monitoring. Radon remains gaseous during transport, while its solid progeny can attach to aerosols; radium may transfer from water into scale, sludge or sediment as conditions change. (A9, pp. 37, 49–55; UK10; UK16)

The missing element is receiving-environment attribution. Without a pre-disturbance ambient gamma and soil/water/sediment reference, a later localised observation cannot be compared to a site-specific baseline. There is no identified UK rule that automatically requires a broad off-site radiological survey for this permit; the recommendation is proportionate technical good practice because the operation acknowledges possible NORM generation.

Required closure: calibrated ambient gamma at fixed site/control points; representative soil, water and sediment where the conceptual model identifies accumulation pathways; actual radon-222 screening of representative gas before sustained venting or flaring; documented geometry and background variation; and event-triggered radionuclide analysis following a spill, unexplained screening result, aerosol/deposition concern or relevant off-site report.

## 9.4 Gap WM-2 - off-site wastewater suitability and final fate

The updated Waste Management Plan and Surface Water Management Plan state that formation water, flowback and contaminated water will be transferred by licensed haulier to an Environment Agency-permitted treatment facility, where it will be treated and discharged under that facility's controls. The public package does not name the receiver, provide its waste-specific acceptance limits, show representative Cloughton treatability, identify its radioactive-substances status, account for chloride, bromide, metals, hydrocarbons and radionuclides in treatment residuals, or identify the ultimate discharge and receiving-environment verification. Historic Preese Hall flowback was routed to Davyhulme under an existing permitted discharge framework; that history is relevant not as a direct analogue, but because it shows why legal permission to receive a waste and technical suitability for its actual composition must be demonstrated separately. (A6; A9; HIST1–HIST2)

Required closure: before transfer, identify the receiving facility and applicable permits; provide representative waste analysis and written acceptance criteria; demonstrate treatability for salinity, metals, organics and NORM; account for sludge, scale, filters and all secondary wastes; identify the final discharge or disposal route; prohibit dilution as evidence of treatment; and reconcile generated, loaded, delivered, accepted, treated, discharged and residual quantities.

## 9.5 Gap WM-3 - vehicle- and equipment-mediated transfer

The AQIA provides wheel washing to minimise construction dust track-out. It does not describe a chemical, saline, hydrocarbon or NORM decontamination control. The application relies on local secondary containment and a pad-wide HDPE surface as tertiary containment if a transfer spill, overflow, connection failure or leak reaches the general pad. Any surface credited with receiving an accidental release is also a possible contact surface for tyres, tracks, wheel arches, underbodies, crane feet, stabilisers, hoses, tools, footwear and removable equipment. Local bunding reduces probability; it does not logically eliminate movement-mediated transfer. (A3; A8, p. 85; UK14)

*Figure 3. Preston New Road wellsite at the end of the drilling phase, 4 August 2018. Mobile plant, tankers, lifting equipment, temporary storage and personnel operate across a shared pad surface. Wet, muddy or discoloured areas are visible, but the image does not establish their composition, source or off-site transfer. Its relevance is procedural: it demonstrates that local containment areas and vehicle movements coexist within an interconnected operational workspace.*

Required closure: defined process/dirty zones and clean routes; final-exit inspection and contained decontamination of tyres, wheel arches, underbodies and exposed equipment; no return across the active surface after cleaning; incident-triggered vehicle quarantine and trace-back; segregated wash water and sludge pending classification; and documented clearance of the exit route and any vehicle that may have left before the affected area was controlled.

## 9.6 Complete material-flow and pathway register

The revised assessment treats environmental escape as a material-flow problem rather than a list of isolated permit domains. The register must follow each introduced, encountered or generated material through every phase, carrier and destination. A contaminant must not disappear from the assessment because it changes phase, follows a drain rather than a fault, travels on a vehicle rather than under its own pressure, or crosses into another permitted facility.

| Material/pathway | Controlled or authorised movement | Unintended or escaped movement | Subsurface, indirect or transformed route |
|---|---|---|---|
| Gas, vapour and airborne material | Flare, authorised vents, engines | Fugitive leaks, drilling-return gas, flame loss, aerosol, dust | Well/cement/annuli; faults/fractures; dissolved-gas exsolution; radon progeny on aerosol |
| Water and other liquids | Tanker transfer, treatment, approved discharge, underground retention | Spill, overflow, runoff, liner failure, wash water, transport loss | Well/annuli; faults/fractures; permeable strata; drains, trenches and buried services |
| Solids and residues | Cuttings, mud, scale, sludge, filters, NORM waste | Skip loss, windblown dust, sediment runoff, track-out | Precipitation from water; deposition from air; mobilisation of subsurface fines |
| Mobile carriers | Licensed transport and controlled equipment removal | Vehicles, tools, clothing, hoses, mobile plant | Livestock, wildlife, vegetation, crops and secondary biological transfer |
| Off-site chain | Permitted treatment, recycling, recovery or disposal | Unsuitable receiver, treatment failure, lost load, unrecorded bypass | Contaminants transferred into effluent, sludge, scale, sediment or secondary waste |

Required closure: a regulator-approved material-flow register mapping source, form, quantity, composition, container or control, release point, carrier, monitoring, trigger, waste code, receiving destination, treatment residual and final environmental fate. The register should be reconciled after every material phase and qualifying incident.

# 10. Well integrity, faulting, fracture control and induced seismicity

## 10.1 Existing safeguards

The conceptual well uses multiple casing strings and cement barriers. DCR requires lifecycle well integrity and independent examination. The draft decision and PO 08 require a fault map, stress analysis, historical/induced seismicity assessment, injection stages/pressures/volumes, methods to constrain fracture extent, action if the permit boundary is crossed, local seismic monitoring and post-fracture reporting. (A1, pp. 23–24, 74–76; A2, p. 17; UK9; ISO7)

## 10.2 Gap FS-1 — decisive geomechanical information is deferred

The final HFP is submitted at least two months before stimulation, after drilling and testing supply additional parameters. This is operationally rational: some values are unavailable before the well exists. It also means the consulted permit package does not contain the final fault interpretation, stress model, uncertainties, fracture geometry, seismic network or adaptive limits. The permit decision therefore authorises a framework rather than the final technical design.

### Finding FS-1 — Critical to stimulation

No stimulation should occur until PO 08 is fully approved. The approved HFP should be treated as a material assurance document, with assumptions, uncertainty bounds, revision history and regulator reasoning preserved and published to the maximum lawful extent.

## 10.3 Gap FS-2 - seismic monitoring architecture materially unspecified

The Environmental Risk Assessment states only that seismic monitoring will be implemented. PO 08 requires proposed measures to monitor local seismicity, but the consulted package does not specify the number and position of stations, surface or downhole instrumentation, baseline duration, magnitude completeness, event-location uncertainty, processing latency, strong-motion coverage, traffic-light criteria, trailing-event period or publication arrangements. The absence of those details does not demonstrate that future monitoring will be inadequate; it means that adequacy cannot yet be assessed. (A2, PO 08; A3)

| Capability | Preston New Road documented architecture | Cloughton position at consultation |
|---|---|---|
| Local detection | Eight surface seismometers in a local array, integrating independent BGS and University of Liverpool data | Local monitoring required by PO 08; station number, geometry and performance not specified |
| Fracture/fault imaging | Twelve downhole geophones in the adjacent well used to detect fracture development and interaction with faults | No adjacent monitoring well or alternative method identified |
| Ground motion at receptors | At least four monitors near sensitive or vulnerable structures | No strong-motion locations or criteria specified |
| Real-time and post-injection response | Traffic-light and operational monitoring used during injection; trailing events informed pauses | Traffic-light, restart and post-injection duration deferred to the HFP |

Required closure: the approved HFP should state the monitoring objective and demonstrate performance rather than merely list equipment: pre-injection baseline; azimuthal coverage; minimum detectable magnitude and catalogue completeness; event-location uncertainty; downhole microseismic monitoring or a reasoned equivalent; strong-motion measurements at representative receptors; real-time processing and regulator access; magnitude, ground-motion, location, frequency and fault-interaction triggers; pump-stop/restart/abandonment rules; trailing-event monitoring; independent verification; and publication of the catalogue, operating chronology and limitations. Cloughton need not reproduce PNR exactly, but it should demonstrate equivalent or better capability for the behaviours relevant to this site. (UK13; UK15)

## 10.4 Gap FS-3 - cross-domain consequences of fault or well signals

NSTA manages induced seismicity and HSE regulates well integrity, while the EA regulates environmental pathways. The division is legitimate, but the application does not define automatic propagation between domains. A pressure anomaly, casing test concern, unexpected loss/gain, seismic cluster, groundwater change or surface report may be individually below a specialist threshold while materially significant in combination.

Required closure: a joint trigger matrix. Defined well-integrity or seismic events must automatically preserve environmental data, increase water/air monitoring, inspect containment/ground condition and convene a documented multi-regulator review. Likewise, a credible environmental signal must be checked against well and seismic records.

## 10.5 Gap FS-4 - prediction, uncertainty and trailing response

The decision asserts low risk because the operation is low volume, but it also requires detailed fault and seismic controls. Volume is relevant but does not alone determine fault response. The HFP should present ranges and

sensitivity, not a single predicted fracture outline, and should specify monitoring after injection ceases because delayed seismic or pressure response is possible in fluid-injection systems.

Required closure: uncertainty distributions for key parameters, real-time comparison of predicted and observed response, cumulative stage accounting, trailing-event monitoring, restart criteria and explicit stop/hold points.

# 11. Noise and vibration

## 11.1 Strength of the assessment

The NVIA is one of the strongest documents in the package. It uses recognised standards, long-duration baseline measurements, attended checks, weather filtering, detailed source data, modelling by phase, candidate-rig assessment and a BAT review. The proposed limits and mitigation are explicit. These provisions should be retained. (A12, pp. 24–59 and appendices)

## 11.2 Gap NV-1 — transient complaint reconstruction

The NMP says measurements will normally be complaint- or authority-triggered and obtained within 48 hours, subject to weather. A transient tonal, impulsive or low-frequency event may no longer exist. More importantly, the complaints procedure says prior monitoring of the source with no exceedance can be treated as evidence that there is no breach, even where the complaint occurs under different operating and meteorological conditions. (A12, pp. 123–126)

Required closure: preserve contemporaneous operational state, equipment status, wind and any site sound log; take rapid attended measurements where possible; and state that earlier unmatched monitoring is contextual, not dispositive. Repeated credible reports should trigger temporary logging at the receptor or a validated proxy.

## 11.3 Vibration and induced seismicity boundary

The NVIA appropriately treats mechanical vibration and scopes induced seismicity to NSTA. The assurance system must nevertheless provide one public route and common event record for “felt vibration,” because a member of the public cannot be expected to identify whether the source is machinery, traffic, ground-borne vibration or seismicity.

# 12. Accident management, complaints and cross-domain escalation

## 12.1 Accident Management Plan

The ERA contains tables for spills, loss of containment, fire, flooding, vandalism and equipment failures, with mitigations such as the liner, spill kits, inspections, emergency response and groundwater monitoring. The decision nevertheless records that no dedicated Accident Management Plan was submitted and concludes that other information is sufficient. (A3, pp. 9–12, 21–27; A1, p. 28)

EA guidance requires a plan identifying potential incidents, causes, consequences, prevention and response. Dispersed references can contain the ingredients but make command, version control, exercises, contacts, data preservation and recovery difficult to audit. (UK8)

### Finding AM-1 — High documentary/integration gap

A controlled, stand-alone or clearly indexed Accident Prevention and Management Plan should be approved before construction. This does not contradict the EA’s legal conclusion; it addresses the practical auditability of the assurance system.

## 12.2 Complaint systems

Odour complaints have forms, action logs and potential diaries. Noise complaints have a defined monitoring and reporting route. General environmental complaints are recorded and reported according to severity. These are useful but separate systems. (A9, p. 63; A12, pp. 123–126; A13, pp. 33–35)

## 12.3 Gap AM-2 — no integrated event architecture

The plans do not require all reports to use a persistent event identifier or mandate a cross-domain search. A report of bubbling water, for example, may not automatically preserve groundwater levels, rainfall, ditch condition, methane, well pressure, mud losses, seismicity and photographs. Separate closure can therefore occur even when the combined pattern is the material evidence.

Required closure: one 24-hour public route and one event register. Every event should capture location, time, duration, media, weather and activity; preserve relevant raw data; assign domains and authorities; record hypotheses and tests; state closure reasons; and allow reopening when related evidence emerges.

### 12.4 Cross-domain trigger examples

| Combined signal | Minimum integrated response |
|---|---|
| Odour + methane/VOC anomaly | Immediate LDAR/source check; preserve wind, pressure, separator, flare and ambient data; speciated sample if unresolved. |
| Bubbling water + chemistry/level change | Paired water/gas sample; dissolved gas and provenance methods; inspect well/containment; compare rainfall and pressure. |
| Felt vibration + pressure or seismic event | Joint NSTA/HSE/EA review; preserve high-rate well/seismic data; inspect ground, liner, cellar and water network. |
| New seepage/ponding + settlement/crack | Survey and photograph; drainage/groundwater levels; liner/ditch inspection; temporary monitoring; CSM review. |
| Elevated gamma screening + sediment/water anomaly | Confirm with calibrated instrument and controls; radionuclide-specific laboratory analysis; review NORM waste and drainage records. |
| Repeated sub-threshold changes across domains | Mandatory cumulative-pattern review rather than independent no-exceedance closure. |

### 12.5 Incident-derived failure-mode synthesis

The case review in Appendix E is not used to predict that the same outcome will occur at Cloughton. It tests the proposed architecture against ways in which real operations have escaped observation or control: unknown source composition, nominal control performance, missing mass balance, warnings without automatic hold, unchanged conceptual models, and transfer of contaminants into off-site residuals or receiving media.

| Case | Established transferable lesson | Cloughton closure |
|---|---|---|
| Preese Hall / Davyhulme | A permitted receiver and discharge route are not substitutes for waste-specific suitability, treatability and residual-fate evidence. | Named receiver, acceptance limits, representative treatability, NORM status, residual and final-discharge accounting. |
| Blacktail Creek produced-water pipeline | A measurable inventory discrepancy may continue for a prolonged period if mass balance and alarm response do not compel shutdown. | Dual-point reconciliation, defined discrepancy thresholds, automatic hold and immediate reporting. |
| Measured unlit/inefficient flares | Assumed destruction efficiency can materially overstate performance where a flare is unlit or inefficient. | Continuous flame status and operating envelope, quantified venting, commissioning and representative performance verification. |
| Rager Mountain storage-well failure | Known degradation information can exist without being translated into the active risk model or emergency capability. | Mandatory model revision, condition-based intervention and tested response calculations/equipment. |
| Primrose flow-to-surface events | Unexpected pathways may require active testing of alternative conceptual models rather than repeated explanation within the original model. | Boundary-testing, integrated surface/subsurface investigation and explicit conceptual-model revision triggers. |
| Pennsylvania treatment discharge/sediment | Treatment can transfer contaminants from water into sediment or residuals rather than eliminate mass. | Monitor effluent and residuals; receiving-water/sediment checks where source analysis identifies accumulation risk. |

## 13. Restoration, closure, aftercare and permit surrender

The permit surrender process requires the regulator to be satisfied that necessary measures have been taken and the site no longer poses an unacceptable risk. The draft decision recognises the baseline report as the reference for cessation. PO 01 requires post-decommissioning groundwater monitoring, but duration, frequency, stability tests and stop criteria remain undefined. (A1, pp. 25–26; A2, p. 15)

### 13.1 Gap CL-1 — undefined aftercare endpoint

“Monthly after operations” does not state how long monitoring continues, whether it spans recharge seasons, what trend constitutes stability, how the network is maintained after surface restoration, or what requires reopening. A short clean record after cessation could miss delayed migration or rebound.

Required closure: a minimum risk-based period covering at least one full recharge cycle after the final potentially polluting activity and restoration, extended where trends, anomalies, unresolved incidents or well-integrity conditions require. Stop criteria should include stable levels/chemistry, no adverse trend, resolved incidents, verified site condition and regulator approval.

## 13.2 Data and evidential preservation

Raw monitoring data, calibration, chain of custody, borehole logs, models, operational time series, complaints and investigation records should be preserved for the permit lifecycle and a defined period after surrender. Derived summaries alone are insufficient for later reconstruction.

# 14. Ranked gap register

| ID | Domain | Grade | Class | Evidence | Assurance consequence | Closure | Confidence |
|---|---|---|---|---|---|---|---|
| G-01 | Baseline / Article 22 | Critical | A | EA states baseline report absent; soil and groundwater reference condition not complete. | Cessation comparison and public review lack fixed reference. | Complete full soil/groundwater baseline before disturbance; publish approval. | High |
| G-02 | HFP / fault model | Critical | A/F | Fault, stress, fracture and seismic plan deferred to PO 08. | Stimulation risk envelope not reviewable now. | Approve and disclose HFP; uncertainty, stop and revision rules. | High |
| G-03 | Groundwater duration | High | B/F | Three monthly baseline samples only. | One seasonal window; weak trend/attribution. | 12 months or site-specific statistical justification. | High |
| G-04 | Hydrostratigraphy | High | B/E/F | Perched superficial water acknowledged; only upper bedrock monitored. | Shallow pathway can remain outside network. | Separate superficial/bedrock or multilevel design. | High |
| G-05 | GW parameters/triggers | High | A/F | Analytes, LOQs, interpretation and triggers deferred. | Cannot judge detection capability or action threshold. | Chemical crosswalk, QA/QC, multivariate and trend triggers. | High |
| G-06 | Surface water receptors | High | B/E | Ditch-water classification only; no off-site network. | No direct evidence of receptor condition or event. | Control/affected beck, ditch, pond/spring and event sampling. | High |
| G-07 | Transient air | High | B/D/E | 4-week passive samples and 30-minute mobile CH4. | Short release and peak cannot be reconstructed. | Continuous CH4 and risk-based VOC/H2S plus meteorology. | High |
| G-08 | Integrated incidents | High | B/E | Separate plans and regulators; no common event ID. | Coincident signals can be closed independently. | One event register, data hold, cross-domain review and reopening. | High |
| G-09 | Accident plan | High | B | No dedicated AMP; controls dispersed. | Operational response and audit trail fragmented. | Controlled AMP with drills, contacts, scenarios and recovery. | High |
| G-10 | Ground condition | High | E/F | No repeat topography/drainage/crack/ponding baseline. | Physical change cannot be objectively compared. | Survey benchmarks, fixed photos and lifecycle repeat survey. | High |
| G-11 | Aftercare | High | B/F | Duration and cessation criteria deferred. | Delayed change may not be captured. | Full recharge-cycle minimum, stability and reopening criteria. | High |
| G-12 | LDAR details | Moderate | A/D/E | PO 05 plan not yet available. | Source-level detection/repair cannot be audited. | Component inventory, thresholds, frequency, repair verification. | High |
| G-13 | Flare testing | Moderate | A/B | Annual test may be omitted if <10% annual operation. | Short appraisal may have no direct representative stack test. | Commissioning and phase-specific testing. | Moderate |
| G-14 | Soil plan | Moderate | A/E/F | No final grid, depths, analytes or decision rules. | Baseline may not represent source zones. | Risk-zoned ISO 18400 sampling and archived controls. | High |
| G-15 | NORM baseline | Moderate | B/E | Operational waste controls but no environmental reference. | Later off-site observation difficult to attribute. | Calibrated fixed/control gamma and risk-based soil/water baseline. | Moderate |

| ID | Domain | Grade | Class | Evidence | Assurance consequence | Closure | Confidence |
|---|---|---|---|---|---|---|---|
| G-16 | Retained-fluid verification | Moderate | A/F | Waste table states “Monitoring: None.” | No explicit indirect verification of deep waste behaviour. | Mass balance, pressure, flowback, fracture and integrity reconciliation. | High |
| G-17 | Noise complaints | Moderate | E/F | Monitoring up to 48h later; prior monitoring may be treated as evidence. | Transient event may be missed or wrongly excluded. | Rapid capture; prior unmatched data non-dispositive. | High |
| G-18 | Odour integration | Moderate | B/F | Detailed odour plan but no fixed response time/cross-domain hold. | Short event may dissipate and data may not be preserved. | Time-bound response and automatic methane/operational correlation. | High |
| G-19 | Public disclosure | Moderate | D/F | Approved pre-op plans/data mainly supplied to EA; publication not explicit. | Independent scrutiny and trust reduced. | Publish plans, raw/validated summaries and regulator decisions. | Moderate |
| S-01 | Noise assessment | Strength | E/F | Long baseline and recognised assessment methods. | Provides credible phase-specific acoustic evaluation. | Retain and implement. | High |
| S-02 | Containment | Strength | A/F | Liner, ditch, bunding, testing and inspections. | Strong prevention layer if construction/integrity verified. | Retain; add acceptance criteria and verification. | High |
| S-03 | Odour records | Strength | B/F | Action log, forms, laboratory sampling and diaries. | Good event documentation within odour domain. | Retain and integrate. | High |
| S-04 | PO 08 | Strength | A | Detailed HFP requirements and post-fracture reporting. | Can close major geomechanical gaps before stimulation. | Enforce, disclose and integrate with environment. | High |
| G-20 | Drilling-return gas | High | B/E/F | Waste Gas Plan limited to production testing; drilling gas-handling chain not shown. | A material source can remain outside modelling and monitoring. | Complete source/process diagram; closed or justified captured system. | High |
| G-21 | Air geometry/reconstruction | High | B/E/F | Fixed passive sites are not integrated with changing receiving sectors and event source terms. | A short plume may be missed or irreconstructable. | Continuous meteorology, whole-site/event monitoring and model rerun. | High |
| G-22 | Off-site waste chain | High | A/B/E | Receiver, acceptance, treatability, residual and final fate not demonstrated. | Transfer may end the evidential chain without proving environmental fate. | Named receiver, acceptance/treatability and cradle-to-grave mass balance. | High |
| G-23 | Vehicle/equipment transfer | High | B/E/F | Wheel wash is dust-focused; no incident decontamination or clean/dirty zoning. | Tertiary containment can be bypassed by mobile carriers. | Contained decontamination, quarantine, trace-back and residue classification. | High |
| G-24 | Seismic architecture | Critical to stimulation | A/E/F | PO 08 requires monitoring but no network performance is specified. | Fault interaction and trailing response capability cannot be judged. | Performance-based surface/downhole or equivalent network plus ground motion and real-time rules. | High |

# 15. Proposed permit-condition schedule

The following wording is offered as a technical schedule for regulatory consideration. It is not formal legal drafting and should be adapted by the Environment Agency or legal advisers.

### PC-01 – Baseline before disturbance

No site clearance, excavation, drainage alteration, well-cellar construction, aggregate placement or other activity capable of altering soil, drainage or groundwater shall begin until the Environment Agency has approved a complete Article 22 soil and groundwater baseline report. The report shall contain fixed locations, depths, strata, parameters, methods, detection limits, QA/QC, statistical interpretation and photographic/survey records.

### PC-02 – Baseline duration

Groundwater level and chemistry monitoring shall cover at least one full hydrological year before relevant disturbance, unless the operator demonstrates, using existing site-specific data and a regulator-approved statistical assessment, that a shorter period represents the relevant seasonal range. The written justification shall be published.

### PC-03 – Hydrostratigraphic network

The network shall separately represent any superficial/perched groundwater and the upper bedrock aquifer where site investigation shows distinct units. Borehole logs, screen/seal intervals, development, hydraulic testing and representativeness shall be approved under ISO 5667-22 or equivalent.

### PC-04 – Water receptor monitoring

Before construction the operator shall establish regulator-approved background/control and potentially affected monitoring points for Burniston Beck and relevant ditches, ponds or springs identified by the conceptual model. The plan shall include water level/flow, field parameters, chemistry, sediment criteria and access contingencies.

### PC-05 — Event-triggered water response

Defined triggers—including spill, overtopping, suspected liner failure, unexplained fluid loss/gain, pressure anomaly, new seepage/ponding, bubbling, sheen, wildlife effect or credible public report—shall require time-bound paired sampling, photographs, field measurements, chain of custody and preservation of operational/rainfall data.

### PC-06 – Chemical monitoring crosswalk

No chemical or stimulation product shall be used until its final composition and concentration have been approved and mapped to relevant monitoring indicators or justified exclusions. The plan shall specify analytes/proxies, media, LOQs, methods, controls, trends and trigger levels.

### PC-07 – High-time-resolution air

Continuous or near-real-time methane monitoring, selected risk-based VOC/H2S measurement, continuous meteorology and synchronised operating logs shall be used during drilling, workover, stimulation, clean-up and testing. Monitoring locations and methods shall be justified against source height, wind sectors, terrain and receptors. Qualifying events shall trigger rapid source sampling and event-specific dispersion reconstruction using actual operational timing and the best available source estimate.

### PC-08 – LDAR

The PO 05 plan shall include a complete component inventory, survey method and frequency, quantitative detection thresholds, repair deadlines, repair verification, inaccessible-component procedure, mass-emission estimation, record retention and escalation to ambient monitoring.

### PC-09 – Flare performance

The operator shall validate flare performance during commissioning and representative operation, monitor flame/pilot status, feed flow, composition, calorific value, temperature and relevant pressure, define stable operating limits, quantify every cold-vented quantity and retain evidence of actual destruction and pollutant performance. Annual-frequency exemptions shall not remove representative testing from a short campaign.

### PC-10 – Ground and drainage baseline

The operator shall complete a georeferenced photographic and surveyed baseline of ground levels, benchmarks, cracks, drainage, culverts, wet ground, ponding and vegetation condition, with repeat surveys at phase transitions, after material incidents, before restoration and during aftercare.

### PC-11 – NORM verification

Before disturbance, the operator shall justify whether a radiological receiving-environment baseline is required. Where required, calibrated fixed/control measurements and accredited soil/water/sediment methods shall be used. Representative gas shall be screened for radon-222 before sustained venting or flaring where the geological and process assessment identifies relevance. Operational screening, aerosol/deposition considerations and event-triggered radionuclide analysis shall be specified.

### PC-12 – HFP approval and disclosure

The approved HFP shall be available before stimulation and shall present fault uncertainty, stress ranges, fracture-containment evidence and a performance-based seismic monitoring design: pre-injection baseline, station geometry, minimum detectable magnitude, catalogue completeness, location uncertainty, surface/downhole or reasoned equivalent monitoring, representative strong-motion coverage, real-time processing, traffic-light/stop criteria, trailing-event duration, restart/abandonment rules and post-fracture geometry. It shall be integrated with water, well-integrity and incident triggers.

### PC-13 – Joint trigger matrix

The operator shall maintain a regulator-approved matrix linking well integrity, seismicity, pressure/rate, fluid balance, air, water, ground condition and complaints. A trigger in one domain shall specify when data preservation, enhanced monitoring and multi-authority review are mandatory in other domains.

### PC-14 – Accident and event management

A single controlled Accident Prevention and Management Plan shall integrate all scenarios, roles, contacts, notifications, monitoring, sampling kits, exercises, contractor duties, evidence preservation, recovery and corrective action. It shall be tested before operations and after material change.

### PC-15 – Public reporting route

A continuously available public reporting route shall record exact time/location, media, duration and evidence; issue a persistent event identifier; acknowledge the report promptly; preserve relevant data; provide closure reasons; and permit reopening when related evidence emerges.

### PC-16 – Aftercare

Post-operation and post-abandonment monitoring shall continue for at least one complete recharge cycle after the final potentially polluting activity and restoration, and longer where trends or unresolved incidents require. Cessation shall require stable levels/chemistry, no adverse trend, verified ground condition and written EA approval.

### PC-17 – Data retention and publication

Raw and validated monitoring data, calibration, chain of custody, borehole logs, model versions, operational time series, complaints, investigations and corrective actions shall be retained for the permit lifecycle and a regulator-approved period after surrender. Validated summaries and approved plans shall be published at defined intervals.

### PC-18 – Complete source and process inventory

Before drilling reaches gas-bearing formations, the operator shall provide a controlled process-flow and emissions diagram identifying every gas- and liquid-bearing vessel, shaker, tank, degasser, mud-gas separator, vent, relief, scrubber, knock-out, flare route, drainage route and emergency bypass. Gas-bearing returns and hydrocarbon-bearing tanks shall be closed or captured unless a source-specific BAT assessment demonstrates why an alternative is necessary and how emissions will be measured and controlled.

### PC-19 – Off-site waste acceptance and mass balance

No formation water, flowback or comparable waste shall leave the site until a named receiving facility has issued written acceptance against representative analysis and the operator has documented the applicable permits, waste limits, treatment method, NORM status, secondary residues and final discharge or disposal route. The operator shall reconcile quantity generated, stored, loaded, delivered, accepted, treated, discharged/recovered and retained in residuals. Dilution shall not be treated as evidence of treatment.

### PC-20 – Vehicle and mobile-equipment decontamination

No vehicle or mobile plant shall leave the active area unless tyres, wheel arches, undercarriage, stabilisers and other potentially exposed surfaces have been inspected and, where necessary, cleaned in an impermeable and fully contained transition area. Following a spill or suspected contact with formation-derived or NORM-bearing material, affected vehicles and equipment shall be quarantined; wash water and residues segregated and classified; any departed vehicle traced; and the clean route, access track and highway inspected before normal movement resumes.

# 16. Conclusions

The Burniston/Cloughton 2 application contains genuine environmental controls and should not be characterised as unmonitored. The central question is whether those controls produce evidence capable of supporting the conclusions claimed for them. On the present documents, several do not.

The most material legal-evidential issue is the incomplete Article 22 baseline. The most material scientific issues are the representativeness and hydrostratigraphic scope of groundwater monitoring, the absence of off-site receiving-water evidence, the inability of four-week air methods to reconstruct short releases, and the deferral of the final fault/fracture/seismic design. The most material governance issue is the lack of a single event and model-revision architecture across environmental, operational and regulatory domains.

Pre-operational conditions are capable of closing several of these gaps. Their existence should not be confused with their completion. Assurance will become testable only when the final designs contain fixed locations, methods, detection limits, triggers, uncertainties, integration rules and post-operation endpoints – and when those documents and resulting data are preserved and reviewable.

### Final position

The draft permit should not be treated as scientifically complete until the Article 22 baseline, groundwater plan, surface-water receptor design, LDAR plan, updated surface-water plan, Accident Management Plan, Hydraulic Fracture Plan, ground-condition baseline and integrated event protocol are approved as one coherent assurance system. The required remedy is not maximal monitoring everywhere. It is monitoring proportionate to the event being tested, placed where a pathway could manifest, operated at a cadence capable of detecting it, and linked to a mandatory response when the evidence challenges the model.

# Appendix A. Detailed standards concordance

| Benchmark | Requirement/principle | Submitted position | Assessment/remedy | Source |
|---|---|---|---|---|
| IED Article 22 / EPR baseline | Baseline report before operation where relevant hazardous substances may contaminate soil/groundwater; cessation comparison. | Decision accepts SCR is incomplete. | PO 01 is groundwater-focused; ensure soil and complete relevant-hazardous-substance baseline. | A1 pp.25–26; EU1–EU2 |
| EPR Schedule 22 | Prevent hazardous inputs; limit non-hazardous inputs so they do not cause pollution; risk-based permit controls. | Groundwater activity permitted with deep injection and shallow monitoring. | Final CSM, monitoring and triggers must demonstrate protection of all groundwater potentially affected. | UK1; A1 pp.23–24 |
| WFD Regulations 2017 | River-basin objectives and prevention of deterioration. | HIA includes WFD assessment; no off-site ambient network. | Permit-level compliance may rely on prevention; operator evidence cannot independently confirm receptor condition. | UK2; A4 section 6 |
| EA OOG monitoring guidance | Baseline, operational lifecycle, decommissioning/post-abandonment monitoring. | Plans cover phases but aftercare detail deferred. | Define lifecycle monitoring, phase transitions and endpoint. | UK3 |
| EA OOG basic baseline | Three sets/three months minimum; more samples for seasonal variation. | Three months adopted. | Site-specific seasonality acknowledged; justify or extend. | UK4; A4 pp.22,28,33 |
| EA statistical guidance | Design around where/what/how often/how long and attribution objective. | Locations and parameters partly TBC; limited temporal resolution. | Write objective-specific design and statistical analysis plan. | UK5 |
| EA groundwater protection | Assess all groundwater that could be affected. | Perched superficial water acknowledged but not separately monitored. | Resolve superficial/bedrock coverage. | UK11; A4 pp.25,33 |
| ISO 5667-22 | Representative monitoring-point design and installation. | Long screen proposed; final design deferred. | Discrete horizons, seals, materials and construction QA. | ISO3; A4 p.28 |
| ISO 5667-11 / 5667-3 | Groundwater sampling, preservation and handling. | ISO 5667-11 cited; details absent. | Sampling SOP, purge/low-flow criteria, preservation, chain of custody. | ISO2; A4 p.28 |
| ISO/IEC 17025 | Competent, impartial, reliable laboratory testing. | Independent laboratory promised; accreditation scope unspecified. | Require accreditation for each method/matrix or justified validation. | ISO6 |
| EA ambient-air guidance / MCERTS | Technique must match objective; method performance and QA. | Passive averages plus brief mobile methane. | Add high-time-resolution methods for transient objective. | UK6–UK7; A7 pp.15–18 |
| EU Methane Regulation comparator | Direct measurement, MRV, LDAR, repairs, verification, vent/flaring limits. | LDAR deferred under PO 05. | Adopt comparable source-level measurement and repair verification, without claiming EU legal force. | EU5; A2 p.16 |
| Commission Recommendation 2014/70 | Baseline and operational monitoring, disclosure and risk assessment for HVHF. | Operation classified low-volume; Recommendation not directly applicable. | Use only as comparator for transparency and adaptive monitoring. | EU4 |
| ISO 18400 | Objective-led soil sampling and contaminated-site investigation. | Soil baseline proposed later, under-specified. | Risk-zoned grid, depths, controls, analytes and decision rules. | ISO4–ISO5; A5 p.34 |
| EPR Schedule 23 / EA NORM guidance | Permit and control NORM wastes arising from oil/gas production. | Gamma spectrum, RPS/RWA and RSR routes proposed. | Operational control is positive; environmental baseline recommended for attribution. | UK10; A9 pp.49–55 |
| DCR / ISO 16530-1 | Lifecycle well integrity, barriers, intervention and abandonment. | Conceptual casing and independent examination. | Integrate integrity triggers with environmental monitoring and data preservation. | UK9; ISO7 |
| EA management-system guidance | Accident plan for pollution/non-compliance events. | No dedicated AMP; ERA and dispersed procedures. | Approve one auditable, exercised integrated plan. | UK8; A1 p.28 |

| Benchmark | Requirement/principle | Submitted position | Assessment/remedy | Source |
|---|---|---|---|---|
| BS 4142 / BS 5228 | Recognised noise assessment and construction control. | Substantially applied. | Retain; improve complaint-event reconstruction. | A12 |

## Appendix B. Application and permit document inventory

| Code | Issuer | Document | Date/version |
|---|---|---|---|
| A1 | Environment Agency | Draft decision document, EPR/YP3623LC/A001 | 23 July 2026 |
| A2 | Environment Agency | Draft permit, EPR/YP3623LC/A001 | 2026 consultation draft |
| A3 | Europa / Zetland Group | Environmental Risk Assessment, issue 250424 | 25 April 2025 |
| A4 | Hafren Water | Hydrogeological Impact Assessment, 3729/HIA, final F3 | 16 January 2025 |
| A5 | Europa / Zetland Group | Site Condition Report, issue 250424 | 25 April 2025 |
| A6 | Europa / Zetland Group | Surface Water Management Plan, RFI response, issue 260115 | 15 January 2026 |
| A7 | Europa / Zetland Group | Air Quality Monitoring Plan, issue 250424 | 24 April 2025 |
| A8 | SOCOTEC UK | Air quality assessment of hydrocarbon appraisal operations, issue 6 | 6 February 2025 |
| A9 | Europa / Zetland Group | Waste Management Plan, RFI response, issue 260119 | 19 January 2026 |
| A10 | Europa / Zetland Group | Waste Gas Management Plan, RFI response, issue 260115 | 15 January 2026 |
| A11 | Europa / service suppliers | Chemical Inventory and SDS Inventory | 25 April 2025 |
| A12 | Spectrum Acoustic Consultants | Noise and Vibration Impact Assessment, V3 | 27 January 2025 |
| A13 | Europa / Zetland Group | Odour Management Plan and Odour Risk Assessment | 24 April 2025 |
| A14 | D. Nye | Formal Objection to Draft Environmental Permit, v1.0 | 6 August 2026 |
| A15 | Europa / Zetland Group | Indicative drilling and well-testing site layout plans, drawings 04-04 and 04-07 | January 2025 |
| A16 | D. Nye / NOAA HYSPLIT | Historical daily and monthly air-parcel trajectory ensemble figures from Preston New Road | October 2018 archive |
| A17 | D. Nye | Preston New Road operational aerial photograph, DJI_0442.JPG | 4 August 2018 |

The Chemical Inventory, Well Schematic, SDS Inventory and Extent of Mining Waste Facility plan were also reviewed. The full public application should be treated as a controlled document set; later versions should preserve superseded copies and a change log.

## Appendix C. Legal, regulatory and technical references

[UK1] UK Government (2016), The Environmental Permitting (England and Wales) Regulations 2016, as amended. https://www.legislation.gov.uk/uksi/2016/1154/contents

[UK2] UK Government (2017), The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017. https://www.legislation.gov.uk/uksi/2017/407/contents

[UK3] Environment Agency (2019, updated 2020), Onshore oil and gas sector guidance: 13. Monitoring emissions for onshore oil and gas activities. https://www.gov.uk/guidance/onshore-oil-and-gas-sector-guidance/13-monitoring-emissions-for-onshore-oil-and-gas-activities

[UK4] Environment Agency (2016/2019), Onshore oil and gas sector guidance (baseline monitoring provisions). https://assets.publishing.service.gov.uk/media/5a818a3f40f0b62302697dc3/Onshore_oil_and_gas_sector_guidance.pdf

[UK5] Environment Agency Chief Scientist's Group (2021), Onshore Oil and Gas monitoring: assessing the statistical significance of changes — report and Annex A. https://assets.publishing.service.gov.uk/media/61a0ddfee90e07044b1ef463/Onshore_Oil_and_Gas_monitoring_assessing_the_statistical_significance_of_changes_-_report.pdf

[UK6] Environment Agency (2024), Monitoring ambient air: choosing a monitoring technique and method; techniques and standards. https://www.gov.uk/guidance/monitoring-ambient-air-choosing-a-monitoring-technique-and-method

[UK7] Environment Agency (current), Monitoring emissions to air, land and water (MCERTS). https://www.gov.uk/government/collections/monitoring-emissions-to-air-land-and-water-mcerts

[UK8] Environment Agency (current), Develop a management system: environmental permits — accident prevention and management plan. https://www.gov.uk/guidance/develop-a-management-system-environmental-permits

[UK9] Health and Safety Executive (updated 2026), HSE's role in onshore shale gas and hydraulic fracturing. https://www.hse.gov.uk/shale-gas/about.htm

[UK10] Environment Agency (2019, updated 2020), Onshore oil and gas sector guidance: radioactive substances activity permits. https://www.gov.uk/guidance/onshore-oil-and-gas-sector-guidance/4-radioactive-substances-activity-permits

[UK11] Environment Agency (2018), The Environment Agency's approach to groundwater protection. https://assets.publishing.service.gov.uk/media/5ab38864e5274a3dc898e29b/Envirnment-Agency-approach-to-groundwater-protection.pdf

[EU1] European Union (2010, consolidated 2024), Directive 2010/75/EU on industrial emissions, consolidated text. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:02010L0075-20240804

[EU2] European Commission (2014), European Commission Guidance concerning baseline reports under Article 22(2) of Directive 2010/75/EU. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014XC0506(01)

[EU3] European Commission (current), Groundwater and Water Framework Directive overview. https://environment.ec.europa.eu/topics/water/groundwater_en

[EU4] European Commission (2014), Commission Recommendation 2014/70/EU on minimum principles for high-volume hydraulic fracturing. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32014H0070

[EU5] European Union (2024), Regulation (EU) 2024/1787 on the reduction of methane emissions in the energy sector. https://eur-lex.europa.eu/eli/reg/2024/1787/oj/eng

[ISO1] ISO (2023), ISO 5667-1:2023, Water quality — Sampling — Part 1. https://www.iso.org/standard/84099.html

[ISO2] ISO (2009), ISO 5667-11:2009, Water quality — Sampling — Part 11: Guidance on sampling of groundwaters. https://www.iso.org/standard/42990.html

[ISO3] ISO (2010), ISO 5667-22:2010, Water quality — Sampling — Part 22: design and installation of groundwater monitoring points. https://www.iso.org/standard/46242.html

[ISO4] ISO (2017), ISO 18400-101:2017, Soil quality — Sampling — Part 101. https://www.iso.org/standard/62842.html

[ISO5] ISO (2018), ISO 18400-203:2018, Soil quality — Sampling — Part 203. https://www.iso.org/standard/65226.html

[ISO6] ISO (2017), ISO/IEC 17025:2017, competence of testing and calibration laboratories. https://www.iso.org/standard/66912.html

[ISO7] ISO (2017), ISO 16530-1:2017, Petroleum and natural gas industries — Well integrity — Part 1: lifecycle governance. https://www.iso.org/standard/63192.html

[UK12] Environment Agency (2021), Onshore oil and gas monitoring: a structured approach to quantifying whole-site methane emissions. https://www.gov.uk/government/publications/onshore-oil-and-gas-monitoring-a-structured-approach-to-quantifying-whole-site-methane-emissions

[UK13] Oil and Gas Authority / North Sea Transition Authority (2021), Summary of PNR-1z interim reports: surface array, downhole microseismic and ground-motion monitoring. https://www.nstauthority.co.uk/media/6149/summary-of-pnr1z-interim-reports.pdf

[UK14] Environment Agency (current), Control and monitor emissions for your environmental permit - track-out, wheel washing and road-going vehicle controls. https://www.gov.uk/guidance/control-and-monitor-emissions-for-your-environmental-permit

[UK15] North Sea Transition Authority (current), Onshore well operations and Hydraulic Fracture Plan guidance. https://www.nstauthority.co.uk/regulatory-information/exploration-and-production/onshore/well-operations/

[UK16] UK Health Security Agency / Public Health England (2014), Review of the potential public health impacts of exposures to chemical and radioactive pollutants as a result of shale gas extraction. https://assets.publishing.service.gov.uk/media/5b9a360140f0b678692eb5ca/PHE-CRCE-009_3-7-14.pdf

[UK17] United Kingdom Parliament (2015), Infrastructure Act 2015, s.50, inserting ss.4A–4B into the Petroleum Act 1998 (statutory definition and safeguards for “associated hydraulic fracturing”). https://www.legislation.gov.uk/ukpga/2015/7/section/50/enacted

[ACAD1] Zalucka, A., Goodenough, A. and Smythe, D. (2021), Acid stimulation: Fracking by stealth continues despite the moratorium in England. Energy Policy 153, 112244. https://doi.org/10.1016/j.enpol.2021.112244

[INT1] NOAA Air Resources Laboratory (current), HYSPLIT atmospheric transport and dispersion model. https://www.arl.noaa.gov/hysplit/

[INT2] Plant, G. et al. (2022), Inefficient and unlit natural gas flares both emit large quantities of methane. Science 377, 1566-1571. https://doi.org/10.1126/science.abq0385

[HIST1] Fylde Borough Council (2012), Report and recommendations of the Shale Gas Task and Finish Group, including Environment Agency evidence on Preese Hall flowback composition, NORM and transfer to Davyhulme. https://www.pendle.gov.uk/download/meetings/id/16876/item_4_scrutiny_study_of_the_potential_for_fracking_in_pendle_-_fylde_borough_council_final_report

[HIST2] Natural Gas World (2012), Fracking waste water and the Manchester Ship Canal (secondary contemporary report supplied by the author). https://www.naturalgasworld.com/fracking-waste-water-manchester-ship-canal

[INC1] US Department of Justice / US Environmental Protection Agency (2021), Blacktail Creek produced-water pipeline discharge enforcement and sentencing. https://www.justice.gov/archives/opa/pr/pipeline-company-sentenced-largest-ever-inland-oil-spill

[INC2] Pipeline and Hazardous Materials Safety Administration (2025), Rager Mountain Well 2244 Notice of Probable Violation and proposed compliance order. https://primis.phmsa.dot.gov/enforcement-documents/12025033NOPV/12025033NOPV_PCP_10172025_%2822-259271%29_text.pdf

[INC3] Alberta Energy Regulator (2016), Root Cause and Regulatory Response Report: CNRL Primrose flow-to-surface events. https://www.aer.ca/documents/reports/IR_20160321-CNRL.pdf

[INC4] Warner, N.R. et al. (2013), Impacts of shale gas wastewater disposal on water quality in western Pennsylvania. Environmental Science & Technology 47, 11849-11857. https://doi.org/10.1021/es402165b

[INC5] US Geological Survey (2018), Radium attenuation and mobilization in stream sediments following oil and gas wastewater disposal in western Pennsylvania. https://www.usgs.gov/publications/radium-attenuation-and-mobilization-stream-sediments-following-oil-and-gas-wastewater

## Appendix D. Definitions and evidential language

| Term | Meaning in this report |
|---|---|
| Baseline | A documented reference condition and range against which later change can be compared; not merely the first available sample. |
| Detection envelope | The behaviours a monitoring system can observe given its locations, media, frequency, sensitivity, processing and reporting. |
| Event reconstruction | The ability to determine what happened, where, when, for how long, under which operating and meteorological conditions, and with what environmental response. |
| Trigger | A predefined observation or combination of observations that requires action, investigation, enhanced monitoring or model review. |
| Conceptual-model revision | Formal reconsideration of source, pathway, receptor and system behaviour when observations depart from assumptions. |
| Off-site receptor monitoring | Monitoring of potentially affected and control locations outside the engineered containment system; it does not presume contamination. |
| Gap | An absent, deferred, under-specified or technically incapable element. It is not automatically a legal breach. |

| Term | Meaning in this report |
|---|---|
| Not demonstrated | The submitted evidence does not establish the proposition. It does not mean the opposite has been proved. |
| Proportionate | Matched to the probability, consequence, uncertainty, receptor sensitivity, event duration and feasibility of detection. |
| Material-flow register | A record following each material from source through phase, control, carrier, monitoring, transfer, treatment residual and final environmental fate. |
| Cross-phase transformation | Movement of a contaminant between gas, liquid, aerosol, scale, sludge, sediment, soil or dust, such that monitoring one phase alone may not establish final fate. |
| Mobile carrier | A vehicle, item of plant, tool, hose, clothing, person or biological receptor capable of transporting material across a physical containment boundary. |

# Appendix E. Incident-derived failure-mode review

Purpose and method. This appendix uses documented incidents and measured performance studies to stress-test the proposed assurance architecture. The cases differ in geology, scale, jurisdiction and activity. They are not direct analogues and are not used to estimate the probability of a Cloughton outcome. A lesson is transferred only where the failure mechanism is architectural: source characterisation, control verification, detectability, alarm response, conceptual-model revision, waste-chain evidence or residual fate.

## E.1 Case register

| Case and source | What is established | Assurance failure exposed | Safeguard transferred to Cloughton |
|---|---|---|---|
| Preese Hall flowback / Davyhulme (HIST1-HIST2) | EA records identified high salts, metals and Ra-226 in flowback and transfer to a permitted wastewater works; contemporary reporting records later licence-related cessation. | Receiver permission and initial capability claims do not by themselves prove continuing waste-specific suitability or final contaminant fate. | Name the receiver; provide current permits, acceptance limits, representative treatability, radioactive status, residual and final-discharge accounting. |
| Blacktail Creek, North Dakota (INC1) | A produced-water pipeline release continued for 143 days and discharged about 29 million gallons; enforcement identified deficient metering, detection and response. | An observable pressure/volume discrepancy does not protect the environment unless it compels shutdown, investigation and reporting. | Meter both ends or achieve equivalent reconciliation; define discrepancy thresholds; automatic hold; immediate notification and retained raw data. |
| Unlit and inefficient flares (INT2) | Field measurements found both unlit flares and inefficient combustion contributed materially to methane emissions compared with standard assumptions. | Nominal destruction efficiency is not measured performance, especially during flame loss or unstable operation. | Continuous flame status and operating-envelope records; quantified venting; commissioning and representative performance verification. |
| Rager Mountain gas storage well (INC2) | PHMSA found that a known history of top-joint/casing corrosion was not adequately incorporated into the active risk programme; the event also tested emergency response capability. | Relevant evidence may exist but remain non-consequential if the risk model and preparedness are not revised. | Explicit condition-based model revision, preventive intervention, and tested emergency calculations, equipment and records. |
| Primrose flow-to-surface events, Alberta (INC3) | Multiple bitumen-emulsion releases required extended investigation; earlier work was inconclusive and later regulatory analysis examined subsurface pathways and operational assumptions. | Unexpected observations can persist when the original containment model is not actively challenged by alternative hypotheses. | Boundary-testing, distributed surface/subsurface monitoring, integrated investigation and mandatory conceptual-model revision triggers. |
| Pennsylvania wastewater treatment and sediment (INC4-INC5) | Peer-reviewed and USGS work documented oil-and-gas wastewater signatures and enhanced/more mobile radium in downstream sediments after permitted treatment discharges. | Treatment may transfer contaminant mass into sludge or sediment rather than eliminate it; effluent-only evidence can miss accumulation. | Waste-specific treatability; effluent, residual and sediment monitoring where source analysis identifies accumulation risk; full mass balance. |

## E.2 Derived architecture

- Source certainty: representative gas, water, waste and aerosol composition must be measured before the final control and monitoring design is treated as validated.
- Control verification: liners, bunds, flares, scrubbers and treatment plants must be assessed by demonstrated performance under representative conditions, not by nominal design alone.
- Mass balance: concentration compliance must not replace accounting for total contaminant mass and its transfer into sludge, scale, sediment, atmosphere or secondary waste.
- Automatic hold points: defined discrepancies, flame loss, abnormal gas, containment failure, waste rejection, seismic/fault interaction and credible environmental observations must suspend the causally relevant activity pending documented review.
- Model revision: unexpected observations must be capable of changing the conceptual model, monitoring design and operating limits.
- Event reconstruction: high-resolution operational, monitoring and meteorological records must be synchronised and preserved before the event dissipates.
- Boundary continuity: responsibility and evidence must continue across vehicles, waste hauliers, treatment facilities, discharge points and permit/regulator boundaries.

## Appendix conclusion

The purpose of the derived safeguards is not to demand that harm be proven after the fact. It is to make a material departure either preventable, rapidly detectable or reconstructable from an unavoidable record. The assurance system should therefore be judged by whether an abnormal release can be hidden by averaging, transferred beyond the site gate, converted into another phase or closed within a single regulatory domain without the combined evidence being examined.

**End of report**